REPORT SE-36

WORLD DATA CENTER A
for
Solid Earth Geophysics

CATALOG OF SUBMARINE VOLCANOES AND HYDROLOGICAL PHENOMENA ASSOCIATED WITH VOLCANIC EVENTS

1500 B.C. TO DECEMBER 31, 1899

September 1984

NATIONAL GEOPHYSICAL DATA CENTER

COVER PHOTOGRAPHS

Left: Nuee' ardente flow on Mt. Lamington, Papua Island, 1951.
Center: Lava fountain, Kilauea Iki, Hawaii, 1960.
Right: Eruption cloud, Mt. Ngauruhoe, New Zealand, May 1972.

(all photographs, University of Colorado)

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DESCRIPTION OF WORLD DATA CENTERS

World Data Centers conduct international exchange of geophysical observations in accordance with the principles set forth by the International Council of Scientific Unions (ICSU). They were established in 1957 by the International Geophysical Year Committee (CSAGI) as part of the fundamental international planning for the IGY program to collect data from the numerous and widespread IGY observational programs and to make such data readily accessible to interested scientists and scholars for an indefinite period of time. WDC-A was established in the U.S.A.; WDC-B in the U.S.S.R.; and WDC-C in Western Europe, Australia, and Japan. This new system for exchanging geophysical data was found to be very effective, and the operations of the World Data Centers were extended by ICSU on a continuing basis to other international programs; the WDC's were under the supervision of the Comite International de Geophysique (CIG) for the period 1960 to 1967 and are now supervised by the ICSU Panel on World Data Centres.

The current plans for continued international exchange of geophysical data through the World Data Centers are set forth in the *Fourth Consolidated Guide to International Data Exchange through the World Data Centres,* issued by the ICSU Panel on World Data Centres. These plans are broadly similar to those adopted under ICSU auspices for the IGY and subsequent international programs.

Functions and Responsibilities of WDC's

The World Data Centers collect data and publications for the following disciplines: Meteorology; Oceanography; Rockets and Satellites; Solar-Terrestrial Physics disciplines (Solar and Interplanetary Phenomena, Ionospheric Phenomena, Flare-Associated Events, Geomagnetic Phenomena, Aurora, Cosmic Rays, Airglow); Solid Earth Geophysics disciplines (Seismology, Tsunamis, Gravimetry, Earth Tides, Recent Movements of the Earth's Crust, Rotation of the Earth, Magnetic Measurements, Paleomagnetism and Archemagnetism, Volcanology, Geothermics), and Marine Geology and Geophysics. In planning for the various scientific programs, decisions on data exchange were made by the scientific community through the international scientific unions and committees. In each discipline, the specialists themselves determined the nature and form of data exchange, based on their needs as research workers. Thus, the type and amount of data in the WDC's differ from discipline to discipline.

The objects of establishing several World Data Centers for collecting observational data were: (1) to insure against loss of data by the catastrophic destruction of a single center, (2) to meet the geographical convenience of, and provide easy communication for workers in different parts of the world. Each WDC is responsible for: (1) endeavoring to collect a complete set of data in the field or discipline for which it is responsible, (2) safe-keeping of the incoming data, (3) correct copying and reproduction of data, maintaining adequate standards of clarity and durability, (4) supplying copies to other WDC's of data not received directly, (5) preparation of catalogs of all data in its charge, and (6) making data in the WDC's available to the scientific community. The WDC's conduct their operation at no expense to ICSU or to the ICSU family of unions and committees.

World Data Center A

World Data Center A, for which the National Academy of Sciences through the Geophysics Research Board and its Committee on Data Interchange and Data Centers has overall responsibility, consists of the WDC-A Coordination Office and seven subcenters at scientific institutions in various parts of the United States. The GRB periodically reviews the activities of WDC-A and has conducted several studies on the effectiveness of the WDC system. As a result of these reviews and studies, some of the subcenters of WDC-A have been relocated so that they could more effectively serve the scientific community. The addresses of the WDC-A subcenters and Coordination Office are given inside the front cover.

The data received by WDC-A have been made available to the scientific community in various ways: (1) reports containing data and results of experiments have been compiled, published, and widely distributed; (2) synoptic-type data on cards, microfilm, or tables are available for use at the subcenters and for loan to scientists; (3) copies of data and reports are provided upon request.

PREFACE

The idea of a comprehensive catalog of hydrological phenomena associated with volcanoes originated in 1979. The author has since collected hundreds of pieces of worldwide data, spanning 3500 years from antiquity to the present. It soon became clear, however, that there are too many pieces of data to include all of the entries in a single volume. Therefore, it was decided to treat the events in three different volumes. This first volume contains a short description of the events from about 1500 B.C. to the end of 1899. The second volume treats those events that occurred between January 1900 and December 1979. In these two volumes a catalog of submarine volcanic eruptions, new islands, tsunamis, seiches, and base surges is given. The third volume summarizes all the known subglacial eruptions and jokulhlaups (that is, glacier bursts that are the consequences of such eruptions).

Not only the known cases are treated, but also those that are doubtful. These are symbolized by a questionmark beside the conventional volcanological abbreviations. In certain cases I have expressed my own view in the discussion of certain phenomena; readers should regard these views as personal opinions only, which can be accepted or rejected on the basis of the results of further research.

ACKNOWLEDGMENTS

The author is very much indebted to the following scientists. The late Mr. Gustav Hantke, whom I remember with great esteem and who gave me invaluable information on the volcanic events of the Aleutian-Alaska belt. I am particularly grateful to Dr. William H. Berninghausen, USA; Professor Rein W. van Bemmelen, The Netherlands; Dr. John H. Latter, New Zealand; Professor Frederico Machado, Portugal; Dr. Maur Neumann van Padang, The Netherlands; Dr. George Pararas-Carayannis, Hawaii; Dr. Thomas Simkin, USA; Professor Sigurdur Thorarinsson, Iceland; and last, but not least, Mr. Daniel C. Shackelford, USA. To Geza Toth and Dr. Laszlo Facsinay, Hungarian geophysicists, are due many thanks for their help in treatment of source material. The author is very indebted to the Museum of Natural History, Reykjavik, Iceland, and personally to Dr. Sveinn Jakobsson for permitting the use of interesting old drawings of submarine volcanoes near Iceland.

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ASSOCIATED WITH VOLCANIC EVENTS
1500 B.C. TO DECEMBER 31, 1899

INTRODUCTION

On the suggestion of Neumann van Padang, the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), has accepted some symbols for the short description of certain volcanic phenomena. These symbols are used in this catalog, but it was necessary to add a few more to them. The symbols used in the present catalog are as follows:

Conventional Symbols

- O eruption in the central crater
- eruption in a parasitic crater
- eruption in a radial fissure
- = eruption in a regional fissure
- subglacial eruption
- normal explosions
- eruptions producing nuees ardentes
- lava flow
- eruption in a crater lake
- eruptions in a lava lake
- extrusion of a lava dome
- Δ extrusion of a spine
- phreatic explosions
- mud flows
- submarine eruption, sublake eruption
- volcanic island
- tsunami

New Symbols

- tornadoes, water spouts, high (vertical) water columns
- seiche
- base surge
- submarine lava flow
- submergence or dennihilation of a volcanic island (used generally only in cases when exact date is known)
- ? doubtful event
- S supplement to a former item

At the end of this volume the reader will find an "List of Locations" in which all the volcanoes (including the unnamed ones) are listed in alphabetical order according to the name of the volcano or, if no name, in terms of the name of the area in which the eruptive center can be found. Names and coordinates generally adhere to the volumes, Catalogue of Active Volcanoes of the World Including Solfatara Fields, published by IAVCEI, and to Simkin et. al, (1981).

At the time of preparation of the present catalog the volumes for Iceland and for the Aleutian -- Alaska belt had not been published. The data for these regions are from geoscientists Berninghausen, Hantke, and Latter as well as Shackelford. In the Catalogue of Active Volcanoes each volcano has a serial number which gives information about the region, about the district within the given region, and about the special serial number of the volcano in question within the district. For instance: 6,3-9 means Tangkuban Prahu (or Parahu), where 6 means Indonesia and 3 means Java. For easy identification of the individual volcanoes we adopted the same system in the "Index of Localities." But, since the volumes for Iceland and for the Aleutian--Alaska belt were not available, the volcanoes belonging to these regions are mentioned without serial numbers, as are volcanoes not mentioned in the Catalogue of Active Volcanoes. Following Simkin (1981), serial numbers are given in this form: 0603-09.

A. EVENTS BEFORE THE BEGINNING OF THE CHRISTIAN ERA

1. Around 1500 B.C. -- Santorini, Aegean Sea

A tsunami accompanied the "Minoan" eruption; it was due to the collapse of the ancient, central cone of the volcanic group. Devastation along Northern Crete, Western Cyprus (Meszaros 1978), the Eastern Mediterranean as far as Ugarit (Rhas Shamra) on the Syrian coast, and along the coast of the present-day Tel Aviv and Jaffa. According to calculations (Yokoyama 1978) the tsunami arrived at the western shore of Anaphi Island from Santorini in 10 min. The northern coast of Crete was reached within 25 min. The waves travelled about 70 min to Western Cyprus, while the Tel Aviv -- Jaffa line was reached after about 105 min. A possible maximum height at the source area of 50 to 89 m was deduced -- the most probable height of the tsunami just at Santorini becomes 63 m (Yokoyama 1978). The eruption of the volcano was (at least partly) submarine and was accompanied by base surges as well (Bond and Sparks 1976).

This tsunami might have had an important historical role since it destroyed the warships of the Minoan Empire and thus the ancient inhabitants of Crete could not protect themselves against the Achaian warriors

Figure 1.-- The site of the greatest known tsunami of volcanic origin: the interior of the Santorini caldera, Aegean Sea. In the foreground part of the island of Thera is visible; in the background is a remnant of the ancient volcanic mount, Therasia. (P. Hedervari)

who came from mainland Greece to conquer them (Luce 1969).

2. About 330 B.C.--Moschylos, Aegean Sea

"It is rumoured, that Chryse Island and the volcano Moschylos near the island of Lemnos were sunk by a shock. If it is true, a huge tsunami should have been generated" (Galanopoulos 1960, p. 375). According to Sieberg (1932) the strong shock had an epicentral intensity of 9° or greater and originated at 40°N, 25°E.

3. 264-241 B.C.--Campi Flegrei del Mar di Sicilia

Between these years and during the first Punic War, submarine eruptions occurred in this area (Imbo 1965).

4. 197 B.C.--Santorini, Aegean Sea

This is the first of three possible dates for the origin of Palaea Kameni Island within the Santorini caldera (Georgalas 1962). In that year a great shock with an epicentral intensity of at least 7° took place in and around Rhodes (Galanopoulos 1961) that might have perhaps been associated with this eruption. See, however, A.D. 46, Santorini as well. Strabo states that the Island of Hiera was formed during an outburst that was accompanied by "flames" (Georgalas 1962).

5. 194 B.C.--Santorini, Aegean Sea

This is the second possible date among three for the origin of the Island of Palaea Kameni within the caldera of Santorini (Georgalas 1962). See also A.D. 46, Santorini.

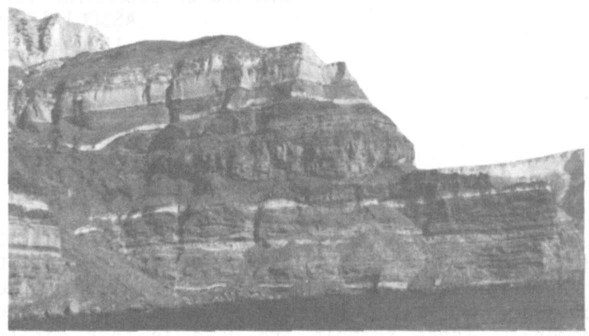

Figure 2.-- A part of the very steep wall of the Santorini caldera at Thera. (P. Hedervari)

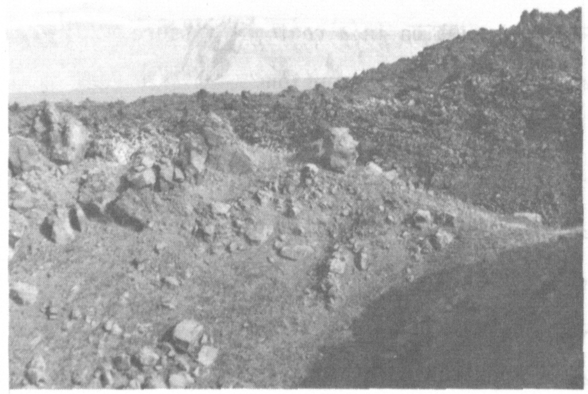

Figure 3.-- Fresh lavas on Nea Kameni Island within the Santorini caldera. In the background the caldera wall of Thera Island can be seen. (P. Hedervari)

Figure 4.-- The main crater of Nea Kameni volcano. (P. Hedervari)

6. 183 B.C.--Vulcanello, Lipari Islands

This was probably a submarine eruption. MacDonald (1972) has mentioned only normal explosions and lava flows from the central crater. According to Imbo (1965), during the activity of Vulcano the craters of Forgia Vecchia and Vulcanello were formed.

7. About 150 B.C.--Taupo Volcanic Centre, Central North Island, New Zealand

There are some indications that about 23-25 km^3 of tephra were formed during a phase of the great cycle of eruptions. Two submarine eruptions also took place (Cole and Nairn 1974). Note added in proof: Walker (Jour. of Volc. and Geotherm. Res., 8, 69-94, 1980) has dated this eruption at about A.D. 31.

8. 91 B.C.--Vulcanello (? or Vulcano?), Lipari Islands

Submarine eruption? (Imbo 1965).

B. EVENTS AFTER THE BEGINNING OF THE CHRISTIAN ERA

9. A.D. 19--Santorini, Aegean Sea

The Island Thia was formed by the effusion of lavas in the caldera of Santorini (Georgalas 1962).

10. 46--Santorini, Aegean Sea

This is the third (and usually accepted) date for the origin of Palaea Kameni Island within the large caldera. The island was formed by repeated lava effusions (Georgalas 1962). An earthquake with an epicentral intensity greater than 7° triggered an explosion within the caldera. The shock was felt on Crete. It was followed by a tsunami that preceded the withdrawal of water some 100 m (Galanopoulos 1960). Epicentral coordinates: 36.5°N, 25.5°E (Sieberg 1932).

11. 79 August 24--Vesuvius, Italy

This event is known as the "Pompeian" eruption. A tsunami was mentioned by Pliny the Younger. The exact date of the outbreak is uncertain. Giorgetti and Iaccarino (1971) gave 79 November 24 as the date of the "explosion of Vesuvio" and said that it was preceded by a very strong, 10° shock on November 23 that can be regarded as a direct trigger. Its epicenter was almost exactly the volcano itself (epicentral coordinates: 40°48'N, 14°27'E--in contrast the coordinates of Vesuvius are: 40°49'17."N, 14°25'34"E). Judging from the degree of intensity, it appears to have been a tectonic shock rather than a volcanic one of A or B type. For the date of eruption in question, Imbo (1966) gave "79 (October 26 ?)".

12. 416--Krakatau (?), Sunda Strait

According to Berninghausen (1969), large destructive waves accompanied a volcanic eruption. The waves were observed at Java, Sumatra, and in Selat Sunda (06°00'S, 105°45'E).

Note: Concerning this eruption and tsunami we have the following information from Shackelford (1980). "It was likely that Krakatau was the site of the eruption, as indicated to me by Gustave Hantke about a year ago. According to him, this tremendous eruption was from the volcanoes of Capi, Karakoto (probably = Krakatau), Batuwara and Kamula. Hantke's data were from some old sources, and neither of us are aware of any volcanoes with those names, so we felt that it was likely to be Krakatau or possibly a South Sumatran volcano. However, the fact that a tsunami accompanied the eruption would seem to suggest to me a submarine or island volcano, of which only Krakatau fits the description of known active volcanoes." In favor of this opinion it can be mentioned that Krakatau lies in Selat Sunda (this is the Indonesian name of the Sunda Strait) in which the waves were observed.

13. 726--Santorini, Aegean Sea

Submarine activity occurred within the caldera. A great quantity of pumice was erupted. An island was formed from the effused lava that united the eruption center with Hiera Island, but it disappeared at a later time. Another possibility is that the new island was formed on the northern side of Palaea Kameni with which it finally was united (Georgalas 1962).

14. 765 July or 766 July--Unknown volcano (Sakura-zima?), Kyusyu

Either a tsunami or a mudflow took place. The phenomenon has been observed at Osumi Island or Osumi peninsula (Iida et al. 1972). Note: The event was associated with a volcanic eruption. Kuno (1962) mentioned an outbreak of Sakura-zima in the year 766, and according to him a new island was born. In contrast, Iida et al (1972) said that an island sank. We suggest the volcano in question was really Sakura-zima, because this mount is situated just in front of Osumi Island where the tsunami (or a mudflow into the sea) was reported. Therefore, 766 appears to be more probable than 765. Sapper (1927) also gave 766, but he listed no details.

15. 10th century--Crater Lake, Oregon

After the paroxysmal eruption of Mount Mazama about 5000 B.C., when 30 km^3 of tephra were injected and a collapse-caldera was formed, a new island emerged from the bottom of the caldera-lake in the

Augustins, Toulouse.

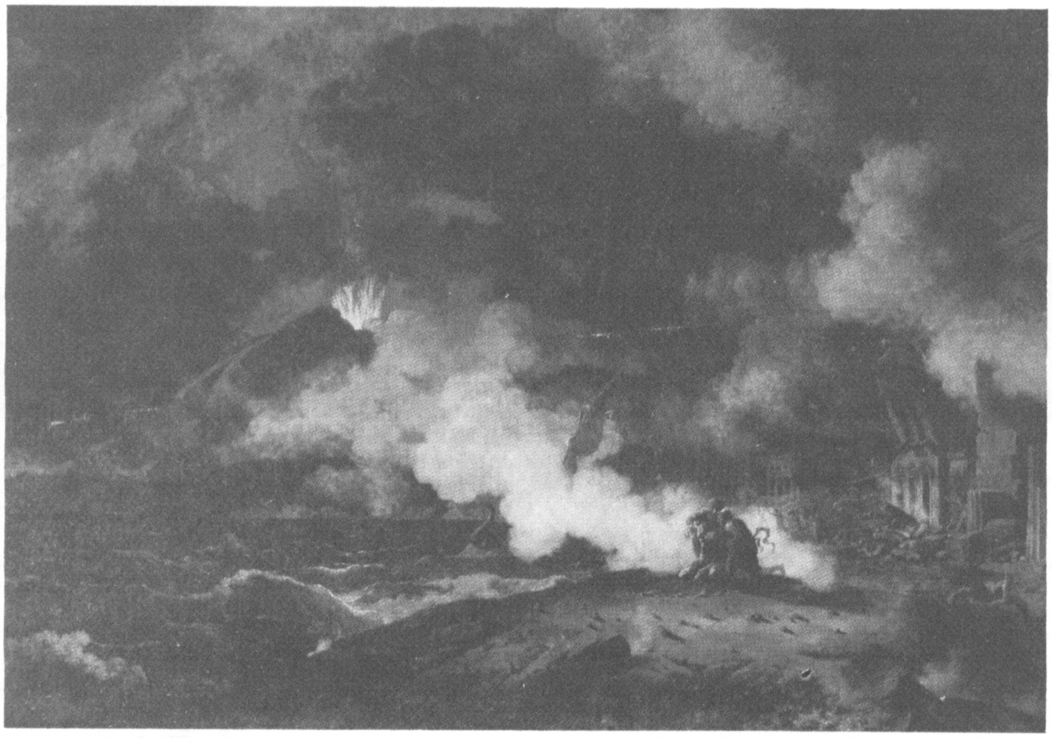

Figure 11/1.-- In 1813, French neoclassic Painter Pierre-Henri de Valenciennes, following Pliny the Younger's account of his uncle's death, painted The Eruption of Vesuvius and the Death of Pliny, now in the Musee des Augustins, Toulouse. (After Natural History)

10th century A.D. This is now known as Wizard Island (Kittleman 1979).

▽ ↑ ★

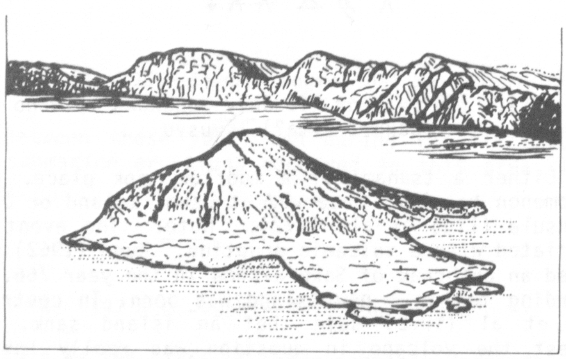

Figure 15/1.-- Wizard Island within the caldera of Mount Mazama (Crater Lake, Oregon). After Cotton.

16. 1050--Santorini, Aegean Sea

Heck (1947) has reported a small seismic sea wave that was associated with a submarine eruption of (or near) Santorini. No eruption of this volcano is mentioned by Georgalas (1962), or by Galanopoulos (1960, 1961); therefore, the event is doubtful. See item 265.

⊼ ↑ ? ⊻ ?

17. 1226, winter--Eldey, Iceland

A submarine eruption and ash fall occurred (Berninghausen 1964).

⊼ ↑

18. 1231--Eldey, Iceland

A submarine eruption accompanied by sand fall or ash fall took place (Berninghausen 1964).

⊼ ↑

19. 1238--Eldey, Iceland

Submarine activity has been reported, but no details are available (Berninghausen 1964).

⊼

20. 1240--Eldey, Iceland

This was a submarine eruption, but no additional data are available (Berninghausen 1964).

⊼

21. 1332--Unnamed volcano, Iceland

Approximate location: 67°10'N, 25°15'W. A submarine eruption was noted, but no further data are available (Berninghausen 1964).

22. 1372--Unnamed volcano, Iceland

Approximate location: 66°40'N, 18°05'W (MacDonald 1972) or 66°37'N, 17°48'W (Berninghausen 1964). A submarine eruption, accompanied by the emergence of a temporary island, was recorded.

23. 1421 May 14--O-sima, Izu-Marina Islands

Submarine outburst from a crater just southeast of Sasikizi, a village on the southern shore of O-sima Island, occurred (Kuno 1962).

24. 1422--Eldey, Iceland

Submarine, new island (Berninghausen 1964).

25. 1456--Unnamed volcano, Iceland

The volcano in question may be located between Iceland and Greenland (van Padang et al. 1967). Its location is between 65.5 and 66.5°N, 25.5 and 30°W (van Padang et al. 1967); 66°N (approximately), 29°34'W (MacDonald 1972); 67°10'N(?), 25°15'W(?) (Berninghausen 1964). An island is shown on a chart published in 1507 and it is remarked that the island was consumed by fire in 1456. According to Berninghausen (1964), a temporary island was formed on the site of the submarine eruption point.

26. 1543--Submarine volcano northwest of Kita-Iwo-zima, Izu-Mariana Islands

No details are known (Kuno 1962). Sapper (1927) has also mentioned an eruption here.

27. 1570 (or 1573?)--Santorini, Aegean Sea

The Island of Mikra Kameni originated from lava effusions. The activity was accompanied by strong explosive phenomena (Georgalas 1962). No data about a tsunami are available (Galanopoulos 1960).

28. 1583--Eldey, Iceland

Submarine activity occurred, but no details are available (Berninghausen 1964).

29. 1596 September 4--Turumi(?), Kyusyu

According to Usami (1966), on this day a shock

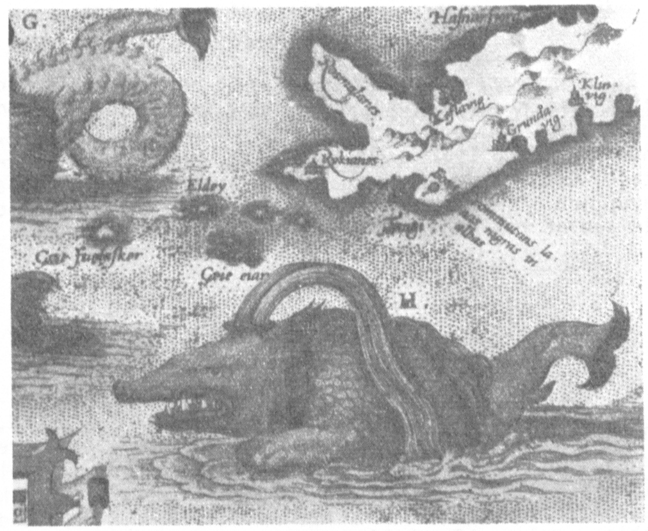

Figure 28/1.-- Islands of the Reykjanes Peninsula on bishop G. Thorlakssons'map printed in 1590, including Eldey. Courtesy of Museum of Natural History, Iceland.

with a Richter magnitude (M) of 6.9 took place near the town of Oita with an epicentral location of 33.3°N, 131.7°E. Concerning this event the author has received a Japanese text and chart from Sato (1977), the source of which is unknown. The text has been translated by Eva Szenasi (1979). Herewith we publish the English version of the original Japanese text:

> During the regime of the 107th ruler [of Japan], Emperor Goyozei [1586-1611] and in the second part of his reining and in the first year of the Long Gladness [in 1596] an earthquake took place on Kyusyu Island, near the town of Oita,-- and the island known as Uriu-jima sunk [?] (or) was covered by lava [?].

According to a note by Sato, in the next year another nearby island, Hisamitsu-jima, also disappeared.

According to the information the author has received from Szenasi, the ancient Japanese text is rather ambiguous; therefore, it is not clear whether there was any lava flow. It must be noted, however, that the only volcano in the near environs of the Beppu Bay, where the two islands disappeared, is Turumi. Kuno (1962) has mentioned only one questionable eruption of this mount, on 687 March 4. No remarks are made concerning any activity in and about 1596. Therefore the volcanic relation of the earthquake in question and that of the disappearance of the two islands is doubtful. It is unlikely--although not impossible--that preceding, during, or following the shock there were lava flows as well. Considering this possibility, which cannot be excluded, we felt it necessary to mention these strange and interesting events in this catalog.

30. 1606 January 23--Hatizyo-zima Nisi-yama, Izu-Mariana Islands

A submarine eruption from a parasitic crater that formed an island near Hatizyo-zima has been recorded. The place cannot be located now exactly, however (Kuno 1962). It is likely, although not certain, that a smaller tsunami was associated with this eruption. The waves were observed around Hachijo Island of the Izu-group (Iida et al. 1972).

?

31. 1627 September--Caraballos (?), North Luzon, Philippine Islands

In this month an earthquake took place at 16°N, 121°E (on mainland) and a tsunami inundated the shore as far as 5 km inland. Trees were uprooted. Russel (1888) has mentioned an eruption of Caraballos, North Luzon, for the same year, and Lamb (1970) has repeated this. Volcano Caraballos, however, is not treated by Sapper (1927) or by Neumann van Padang (1953). This volcano is not indicated in the general map "Volcanoes of the World" (Morris et al. 1979) either. The volcanic nature of the tsunami is thus extremely doubtful. Note added in proof: A thermal feature of Canlaon (strato volcano) is mentioned by Simkin et al. in Volcanoes of the World (Smithsonian Institution 1981). The name of the feature in question is Carabao Killer. Coordinates are 10.41° N, 123.13° E.

?

32. 1632--Giulia-Ferdinandeo Bank (Phlegraean Fields of the) Sicily Sea

This was probably the first known eruption of this volcanic center (Imbo 1965).

33. 1638 July 3 - 23--Unnamed submarine volcano, Azores

Approximate location: 37°52'N, 25°43'W. An ephemeral island was built, having an altitude of 100 m (Neumann van Padang et al. 1967).

= ?

34. 1640 July 31--Komaga-take, Hokkaido

A very strong, explosive eruption with great ashfall occurred. The seismic sea wave killed about 700 persons (Kuno 1962, Heck 1947). Twenty houses were washed away. The tsunami (with a magnitude of 1 and energy of 10^{22} ergs) coincided in time with the start of the eruption. The generating area was Uchiura Bay (Iida et al. 1972). In the Hokkaido-Funkawan area an earthquake took place on the same day (Usami 1966). The total amount of tephra is estimated to be more than 1 km^3 (Sapper 1927).

35. 1650 September 26 - December 6--Santorini, Aegean Sea

A terrific eruption occurred at Cape Columbo. A new island formed that was destroyed by wave erosion. The remaining Columbo Bank is a volcanic dome; its base is at a depth of 300 m and its top at 19 m below sea level. The eruption was preceded by a strong shock, (d = 8° at the epicenter [36.5°N, 25.5°E; Galanopoulos 1961]), and the quake was immediately followed by a devastating seismic sea wave. The first sign of the arrival of the tsunami was the withdrawal of the sea. On Sikinos Island the water receded 100 m or more from the shore, and on Ios the height of the waves was 16 m. In the harbor of Heraklion (Crete) rowboats sank, and at Kea Island a ship was thrown upon the shore. At Patmos the water rose on the east coast of the island to a height of about 30 m and on the west coast it reached a height of 50 m (Galanopoulos 1960). According to these figures it was one of the greatest tsunamis ever observed, and it was particularly powerful as far as tsunamis of volcanic origin are concerned.

Note: We must make a remark here regarding the acoustic phenomenon that accompanied the submarine outbreak on the Columbo Bank, some 16 km northeast of the Kameni Islands of the Santorini caldera. The following considerations are partly based on a personal communication of I. Nagy-Domokos of Budapest in 1978 and partly on a book written by Professor A. Rethly: Meteorological Events and Elementary Calamities in Hungary up to 1700 (Academic Publishing House, Budapest, 1962). In all likelihood the following are quite unknown in English literature. According to these sources, at Marosvasarhely (now known as Tirgu Mures, Rumania), a town in Translvania, a strange loud noise--like the roar of a cannon--was heard on the day the eruption in question began. On the same day a similar loud noise was observed on Cyprus Island. Great masses of floating pumice were seen on the water and pumice was found on many places around the seashore of the islands of the eastern Mediterranean. The distance between Santorini and the westernmost part of Cyprus is about 650 km, and the distance from Santorini to Marosvasarhely is some 1120 km. It is very remarkable that the detonation was heard over such a great distance!

36. 1664--Okinawa-Tori-sima (or Ryukyu-Torisima), Ryukyu Islands

This volcano should not be confused with Tori-sima of the Izu-Mariana Islands. In 1664 a submarine eruption took place, accompanied by a tsunami that damaged many houses (Iida et al. 1972). An earthquake was also observed (Usami 1966). Tsunami magnitude: 1?

37. 1672(?)--Submarine volcano near Smith Rock, Izu-Mariana Islands

An eruption took place at 31°35'N, 140°15'E. No details are known (Kuno 1972).

38. 1673 May 20--Gamkonora, Halmahera

A strong explosive eruption from the main crater was recorded. Many casualties were noted (Neumann van Padang 1951), and a moderate seismic sea wave (magnitude: 1?) accompanied the event (Berninghausen

1969) that was observed first on Halmahera Island (Iida et al. 1972).

○ ↑ ≌

39. 1673 August 12--Ternate Peak, Halmahera

An explosive outbreak from the central crater took place, and a sea wave of considerable force was recorded (Heck 1947). The generating area was the Molucca Passage (magnitude: 1?), and the place of observation was Ternak Island, Indonesia (Iida et al. 1972). Note: The almost simultaneous eruption of these two neighboring volcanoes is very remarkable. Gamkonora had been dormant since 1564 or 1565, and Ternate's last eruption had taken place in June 1659. The simultaneous awakening may suggest the effect of a regional crustal stress. Similar relationships between neighboring volcanoes have been observed in many cases and their renewed activities are often preceded, accompanied, and/or followed by strong tectonic earthquakes in their vicinity, which also suggest the existence of such regional stress.

○ ↑ ≌

40. 1674 February 17--Amboina (???), Moluccas

The name "Amboina" is often cited by Lamb (1970). As a matter of fact, Amboina (Ambon) is the name of a town on a small island just south of the western part of Seram (Ceram) Island, at 3°42'S, 128°19'E. No volcano is known in this region by the same name. This area is very far from the volcanic belt. No mention is made of a volcano in the available catalogs. Amboina ("Amboyna") was originally mentioned on a few occasions by Russel (1888) as an active center of present-day volcanism. The place in question is shown again as a volcano in the Times Atlas of the World (Lamb, personal communication, July 2, 1979) at 3°41'S, 128°10'E. However, the most up-to-date volcanological map (Morris et al. 1979) doesn't indicate any volcano in this region. Therefore, it is very likely that all the seismic sea waves that were observed here were the consequences of tectonic earthquakes and not of submarine or subaerial volcanic manifestations. Hence all the items concerning the alleged "Amboina volcano" will be omitted from our catalog.

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41. 1682 December 13--Unnamed submarine volcano, Azores

Approximate mean position: 37°52'N, 25°43'W. Explosions under the sea led to the formation of large pumice masses that were floating for several days (Neumann van Padang et al. 1967).

= ? ⊼ ↑

42. 1693 Feb. 13 Aug.--Hekla, Iceland

Outbreaks from four craters were recorded. Large blocks were ejected and ash fell in Norway and Scotland. An earthquake and a tsunami along the adjacent coast of Iceland accompanied the eruption (Berninghausen 1964, 1968; Thorarinsson 1970).

↑ ≌

43. 1701 (?)--Giulia-Ferdinandeo Bank (Phelgraean Fields of the) Sicily Sea

An eruption might have caused emergence of a bank, but the island had only an ephemeral life (Imbo 1965).

44. 1703 December 30 (or December 31)--O-sima, Izu-Mariana Islands

A great tsunami, having a height of 6-9 m, followed a strong shock. The shock had a magnitude of 8.2 and was located at 34.7°N, 139.8°E (Iida et al. 1972). Sapper (1927) has mentioned an eruption of O-sima, but it is not treated by Kuno (1962); thus it is doubtful.

The tsunami is assigned a magnitude of 4 by Iida et al. (1972). Calculating from the expression

$$\log E_t = 21.4 + 0.6\ m,$$

where m is the tsunami magnitude, we obtain

$$E_t = 6.31 \times 10^{23} \text{ ergs}$$

for the energy of the tsunami. The earthquake energy--for the Richter magnitude M = 8.2--can be obtained from the formula:

$$\log E = 11.8 + 1.5\ M,$$

where

$$E = 12.59 \times 10^{23} \text{ ergs}.$$

That is, the energy of this tsunami was almost exactly half of the earthquake energy.

Note: If, however, an eruption of O-sima really occurred, it appears likely that the earthquake had initiated (triggered) the outbreak and caused a tsunami at the same time. Thus the eruption and the seismic sea waves were indirectly correlated with one another. Altogether four waves were counted and they caused terrible damage. The south part of the Boso-Hanto peninsula was depressed and 1,020 houses were destroyed here. Some 125 persons lost their lives. At Izu Island 18 boats and 58 houses were destroyed and 56 people died. (Sapper 1927; Heck 1947; Iida et al. 1972; Usami 1966).

↑ ? ≌

45. 1707 May 23 - 1711 September 11--Santorini, Aegean Sea

Nea Kameni Island was formed within the large caldera and between the two older islands, Palaea and Mikra Kamenis (Georgalas 1962).

46. 1707 October 18--Fuji-yama (?), Honsyu

A very severe (M = 8.4) tectonic earthquake took place at 33.2° N, 135.9° E (Usami 1966). The accompanying tsunami (magnitude: 4.8) reached the height of 11.5 m. Many thousands of houses were destroyed by the waves and about 30,000 persons died (Iida et al. 1972). In Susaki, Tosa, there were 12 waves, one after the other; at Kochi the water reached several kilometers inland (Heck 1947). The energy of the tsunami was 1.91×10^{24} ergs, and the energy of the

earthquake was 2.51 x 10^{24} ergs.

Note: The last known eruption of Fuji-yama commenced on December 16, 1707 and lasted to the end of December 1707. In all likelihood the eruption had been triggered by the tectonic shock in question (Nakamura 1975; Hedervari 1979) and thus the tsunami was indirectly correlated with this eruption. On December 16, 1707, a tectonic shock was felt in Suruga Totomi district (Usami 1966). This might have been a direct triggering earthquake.

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47. 1707?--Nishi-yama, Izu-Mariana Islands

A submarine eruption took place at 38°08'N, 139°46' E (MacDonald 1972).

O ↑ ⇗ ⊼

48. 1713--Unnamed submarine volcano, Azores

Approximate location: 37°52'N, 25°43'W. A seismic swarm occurred but no other data are known. The eruption is therefore doubtful (Neumann van Padang et al. 1967).

⊼ ?

49. 1716 September 24 - 27--Taal, Philippine Islands

An outbreak from the crater lake in a radial fissure was observed and arable lands were destroyed. Seismic waves were reported at first (Neumann van Padang 1953); however, Berninghausen (1969) is of the opinion that it was a seiche rather than a tsunami. The wave engulfed a strip of shore more than 16.7 m wide.

↑ ▽ O~

50. 1716--O-sima, Izu-Marina Islands

Sapper (1927) has mentioned a shock and a tsunami, and the seismic wave is mentioned by Heck (1947), too. However, the eruption is doubtful as it is not treated in the Catalogue of Active Volcanoes of the World (Kuno 1962). In addition, the nature of the waves is also doubtful: A "report by Sapper, copied by Heck, of a tsunami in 1716 may have been based on a Rikuzen record of a tsunami occurring during the Kyoho era (1716-1735), probably the Chile tsunami arriving 1730 July 9. How this could be attributed to Oshima is not known."

? ⩳ ?

51. 1718 February 1-12--Pico, Azores

There was a questionable submarine eruption in the company of an eruption from a parasitic crater. Lava flows were also reported (Neumann van Padang et al. 1967)

O ↑ ⇗ ⊼ ?

52. 1720 December 8 - end of December--Don Joao de Castro Bank, Azores

A submarine outburst and an ephemeral island were reported (van Padang et al. 1967). At present in place of the former island there is a shoal with a diameter of 1,500 m and a minimum depth of 14 m. In another work Neumann van Padang (1938) gives 1720 August the birth-date of the island, which was formed by tuff.

O ? ⊼ ↑ ⋏

53. 1731--Tall, Philippine Islands

Eruption from the central crater. New island (Neumann van Padang 1953)?

↑ ▽ ⋏ ?

54. 1737 October 17--Avachinsky, Kamchatka

A great explosive eruption that lasted only 24 hours occurred. There were earthquakes; the third shock was accompanied by a very high tsunami; and the maximum height of the waves has been previously estimated to be about 60-63 m. Recent estimations, however, give 30 m as a probable value. Houses and boats were lost, and many people died (Vlodavetz and Piip 1959, Sapper 1927, Iida et al. 1972). The seismic sea wave in question is known as "Cape Lopatka tsunami" and might have had a tsunami magnitude of 5 on Iida's scale. (Energy: 2.51 x 10^{24} ergs). Heck (1947) gave the date erroneously as 1737 October 6. Sapper (1927) has mentioned that a jokulhlaup (glacier-burst) also occurred. Note: It is noteworthy that at this time another volcano of Kamchatka, namely Kliuchevskoi, also erupted between 1737 October 6 and October 14 (Sapper 1927), but as this volcano is situated rather far from Cape Lopatka it probably had nothing to do with the tsunami. It appears likely that the Cape Lopatka tsunami might have been only indirectly correlated with the Avachinsky eruption; in all probability the outburst of this volcano was initiated (triggered) by a tectonic shock that caused a tsunami at the same time.

↑ ⩳ ⩚

55. 1741 August 23 - 29--Osima-O-sima, Hokkaido

A very powerful eruption, great ash fall, and darkness occurred during the daytime. The tsunami that took place during the second paroxysm (August 29) killed 1,467 persons and washed away 729 houses on the western coast of O-sima peninsula, and 8 persons and 82 houses were lost on the coast of northern Honsyu. The seismic sea wave was probably caused by a submarine dislocation near the volcano (Kuno 1962, Iida et al. 1972). Usami (1966) has mentioned 1741 August 28 as the date of the earthquake that occurred at 41.5°N, 139.4°E, with a Richter magnitude of 6.9. Note that the coordinates of the volcano are 41°30'N and 139°22'E. The volume of pumice fall and flow is estimated to be 1.9 km^3 (Katsui et al. 1978). Note: Accepting this value for the tephra and applying the expression

$$M_e = \frac{\log V + 4.95}{1.5936957} \qquad \text{(Hedervari 1963)}$$

where V is the volume calculated im m^3 and M_e the eruption magnitude, we get for M_e the value of 8.93. As

$$\log E_e = 11.0 + 1.6\ M_e,$$

where E_e is the energy of the tephra eruption (we mean the thermal energy), the result will be:

$$E_e = 1.94 \times 10^{25} \text{ ergs.}$$

The energy of the M = 6.9 shock, calculated from the formula

$$\log E = 11.0 + 1.6\ M$$

is

$$E = 1.09 \times 10^{24} \text{ ergs},$$

which is only a very small proportion of the released thermal energy. The tsunami magnitude of the seismic sea wave was assigned as 3.0 (Iida et al. 1972), which corresponds to a tsunami energy of 1.6×10^{25} ergs. As it can be seen:

$$E < E_{ts},$$

where E_{ts} is calculated tsunami energy; therefore, one concludes that the tsunami in question was not created directly by the earthquake because the released seismic energy was too low. We can suppose, therefore, that the dislocation at the source of the tsunami was not of seismic but of volcanic origin--probably a sudden vertical displacement occurred because of a partial collapse of the ocean bottom and the underlying rocks into the secondary magma chamber. By the term "secondary magma chamber" we mean a more or less lens-shaped cavity filled with rock-melts and gases that is found just beneath the volcano at a normal depth of only a few kilometers. It should not be confused with the primary magma chamber; that is, the domain of fresh magma generation that is at a depth of many tens or one or more hundreds of kilometers beneath the surface.

It is noteworthy, furthermore, that this extraordinarily great eruption belonged to class VII of Tsuya for which the thermal eruption magnitude is 9.0625 ±0.3125 (Hedervari 1963).

○ ? ↑

56. 1749 August 11 (or August 6?)--Taal, Philippine Islands

An eruption took place in the crater lake, from the central vent, and at the same time from a parasitic crater. Neumann van Padang said that destruction of arable lands also occurred. A tsunami is indicated in this volume of the Catalogue, but the event is not mentioned by Berninghausen (1969).

○ ↑ →

57. 1754 May 13 - December 4--Taal, Philippine Islands

An outbreak was noted in the crater lake, from the central vent, and also from a parasitic one. Destruction of arable lands and a tsunami occurred (Neumann van Padang 1953). Berninghausen (1969) has mentioned a lake seiche rather than a true tsunami.

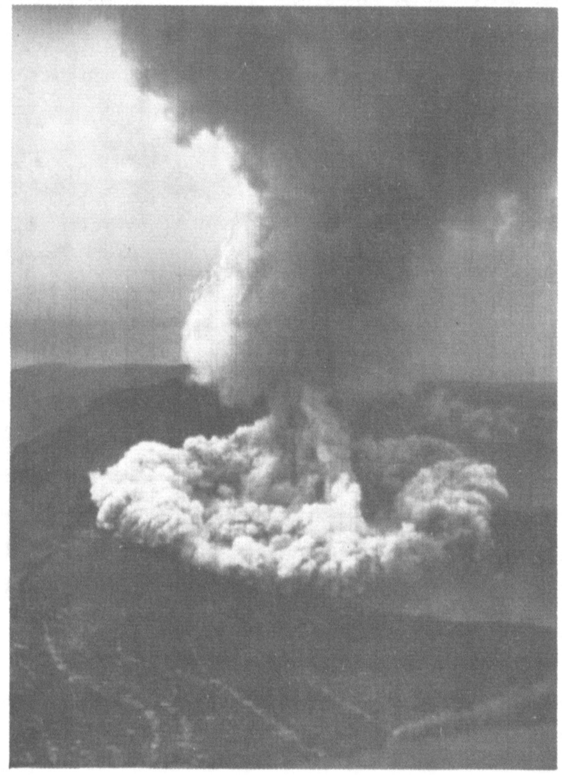

Figure 57/1.-- Development of a base surge on September 28, 1965, in the crater lake of Taal volcano, Philippine Islands.

The wave, together with the volcanic ejecta (base surge?) destroyed the nearby towns or villages (Taal, Lipa, Sala, and Tanuan) and washed out the road on the west side of the lake. This event took place on November 28, 1754. See figs. 57/1 and 57/2.

○ ↑ ? ?

58. 1757--North of Ceylon, near Pondicherry, India

An island made of volcanic scoria has emerged from the sea at approximately 12°N, 80°E (Gutenberg and Richter 1954). This was also mentioned by Sapper (1927) and Neumann van Padang (1938). According to Neumann van Padang the coordinates were: 11°45'N, 80°45'E. No data is available about the disappearance of this tiny island, which remains nameless.

59. 1757--Azores

According to Neumann van Padang (1938), 18

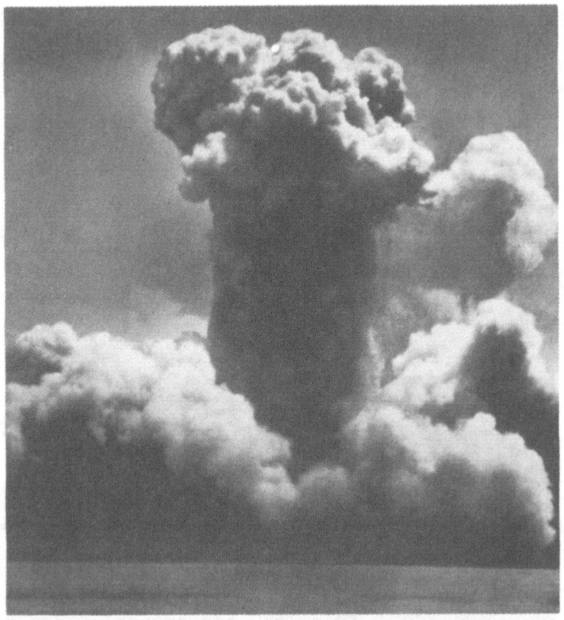

Figure 57/2.-- The eruption cloud, with a form similar to that of atomic blasts. after spread-out of the base surge, Taal Volcano.

islands came into being during this year.

ㅈ ★

60. 1760--Konjushi, Aleutian Islands

This volcano is situated at 52°07'N, 175°W (Neumann van Padang 1938) and forms a little island. the activity in 1760 is doubtful (Latter 1979; Shackelford 1980).

★ ?

61. 1761 April 17 - 18(?)--Santa Barbara (Terceira), Azores

Huge explosions that emitted water jets, gases, and black cinder took place (van Padang et al. 1967). Note: According to Figure 12 of the Catalogue of Active Volcanoes, Part XXI, the 1761 eruptions (explosions) occurred at three different localities along a line and within a distance of 3 km.

62. 1761 May 3--Unnamed submarine volcano, equatorial Atlantic

A small "island"--as a matter of fact a mass of floating pumice--was seen at 0°23'S, 19°10'W (Neumann van Padang et al. 1967).

63. 1763 September 1--(Probably) Ternate Peak, Halmahera

A wave accompanied an eruption. The sea fell 9.1 m and then rose suddenly (Heck 1947, Berninghausen 1969). Lamb (1970) gave the following area as the place of the volcano in question: 2°N-3°S, 125°E-131°E. In this region only the Ternate erupted in 1763.

64. 1768--Bogoslof, Aleutian Islands

The first report and first appearance of Ship Rock or Sail Rock was noted (Bullard 1968, Latter 1979). Its actual appearance may be much earlier.

↑ ★

65. 1773 October--Submarine volcano west of Ibugos, islands north of Luzon, Philippines

No details (Neumann van Padang 1953). Doubtful.

?

66. 1773 (?)--Didicas Rocks, islands north of Luzon, Philippine Islands

No details (van Bemmelen 1970, Neumann van Padang 1953). Doubtful.

?

67. 1779 November - 1782 January 18--Sakura-zima, Kyusyu

A great explosive eruption has been noted from a parasitic crater. According to Neumann van Padang (1938), between 1780 September 9 and 1782 January 28, 9 islands were formed in the northeast coast of the volcanic island by submarine lava eruptions and also by the upheaval of the sea bottom. From 1779 until early 1782, further submarine outbreaks took place in the same region, accompanied by tsunamis. A great seismic sea wave was reported in 1779 (Kuno 1962). For other greater tsunamis see the later items (Iida et al. 1972).

↑ ★

68. 1780 September 9--Sakura-zima, Kyusyu

Further eruption within the sequence, accompanied by an earthquake (Usami 1966) and seismic sea wave of magnitude 0, occurred (Iida et al. 1972). Waves up to 6 m were observed.

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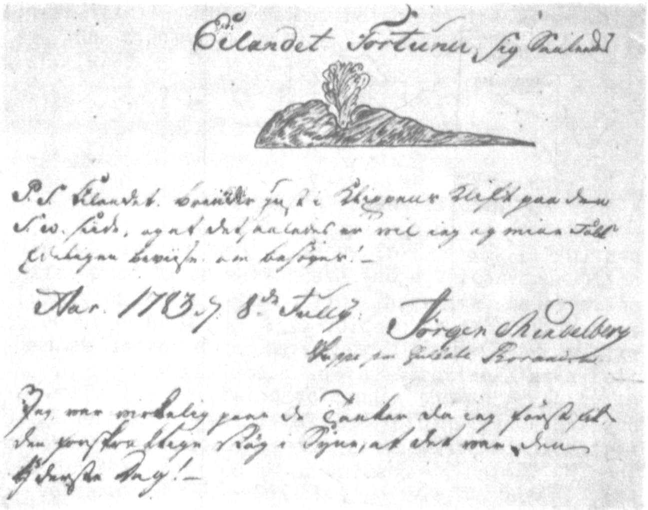

Figure 73/1.-- The end of Captain Mindelbergs' report to the Danish Government on the submarine eruption off Reykjaness in 1783, with a sketch of Njey. Courtesy of the Icelandic National Archives and Museum of Natural History, Iceland.

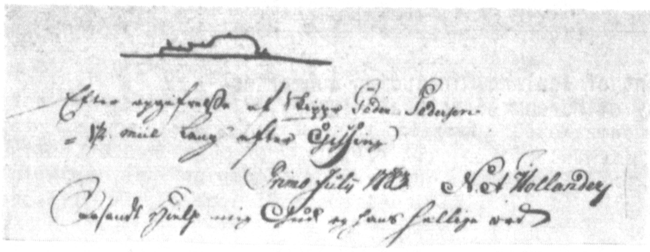

Figure 73/2.-- Captain P. Pedersens' sketch of Nyey. Courtesy of the Icelandic National Archives and Museum of Natural History, Iceland.

69. 1780 October 31--Sakura-zima, Kyusyu

An outbreak, accompanied by an earthquake (Usami 1966) and tsunami of magnitude 0 (Iida et al. 1972), were observed.

70. 1780 (?)--Submarine volcano near Kita-Iwo-zima, Izu-Mariana Islands

No details (Kuno 1962). Doubtful.

71. 1781 April 11--Sakura-zima, Kyusyu

The eruption on this day was accompanied by a tsunami of magnitude 1 and a mudflow (Iida et al. 1972). Usami (1966) has mentioned an earthquake Three boats were overturned and 15 people were drowned by the tsunami.

72. 1781--Unnamed volcano, Tonga Volcanic Group

It is located at 20°22'S, 175°18'W, and is probably identical with Fonua Fo'ou (synonym of Falcon

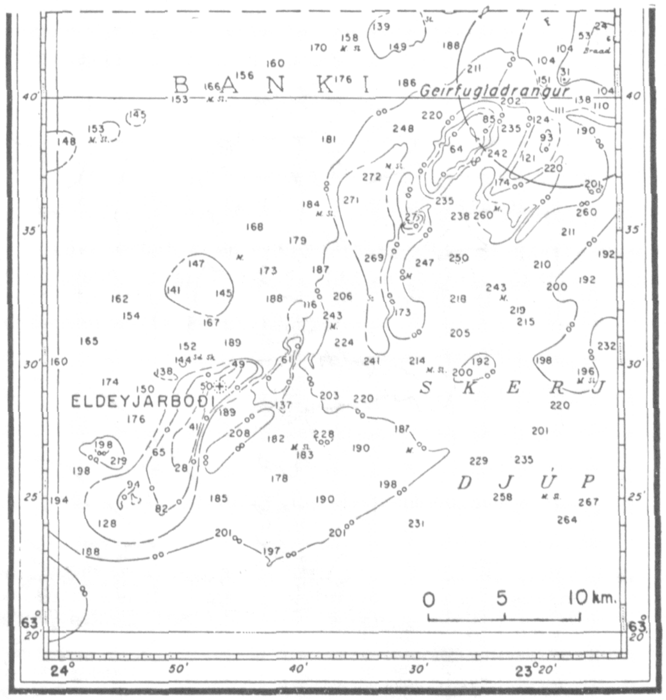

Figure 73/3.-- Bathymetric map of the area around Eldey (Eldeyjarbodi) where submarine eruptions occurred in 1783 and 1830 and probably many other times. Icelandic Hydrographic Service, courtesy of the Museum of Natural History, Iceland.

Island). A submarine eruption was noted near Culebras Bank (another synonym for the same island). No further data are available (Richard 1962). The event is doubtful. It is noteworthy, however, that the Catalogue of Active Volcanoes mentioned an eruption of Falcon Island in the same year, due to which a new island was--allegedly--formed. We interpret these two events to be the same.

73. 1783 May--Eldey, Iceland

An explosive submarine eruption accompanied by the birth of a new island known as Nyo or Noyoe (New) occurred. A very great quantity of pumice was formed (Berninghausen 1964). The new island was located some 50 km southwest of the western coast of Iceland. Nyo was destroyed by wave erosion in less than a year, leaving a submerged reef 9-55 m below sea level. The floating pumice covered the sea for a distance of 240 km, greatly impeding the progress of ships in the area. It is important to note that the disastrous outburst of Laki fissure, 360 km to the east of this new island, began about a month later (Bullard 1968). Note: In the period 1783-1785 not less than 8 volcanoes erupted in and very near Iceland, these events were physically related to one another. At least we can suppose such a correlation among them on the basis of the almost simultaneous activity. The Laki fissure-eruption was the greatest lava flow in history, producing 12 km^3 of rock melts and an additional 2 km^3 of tephra.

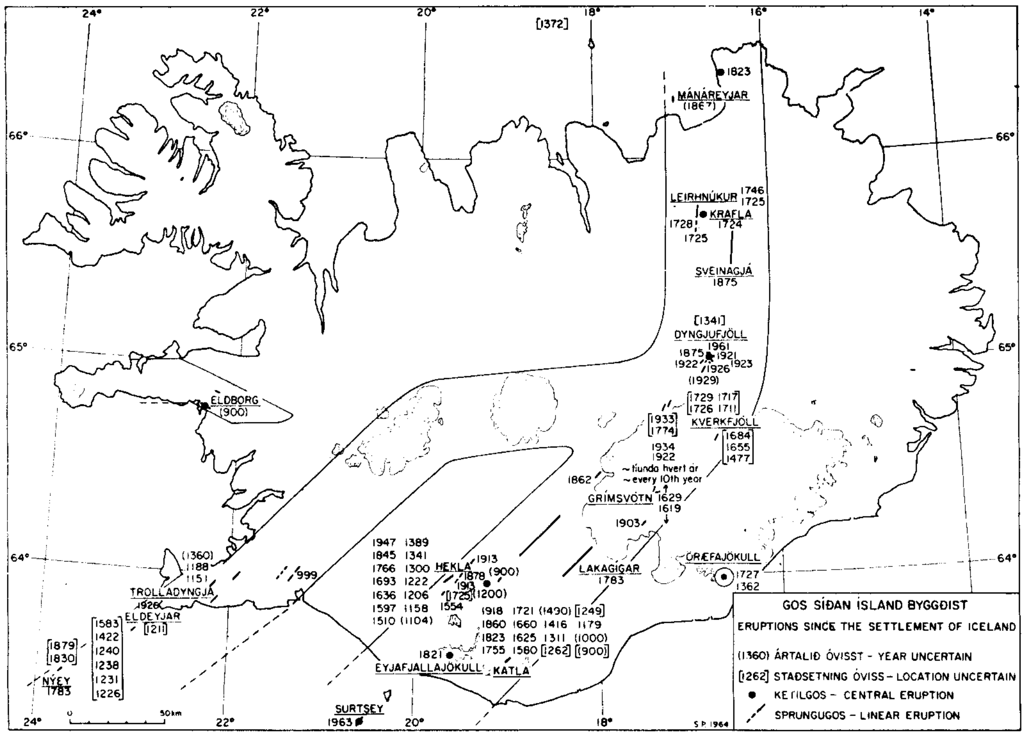

Figure 73/4.-- Eruptions since the settlement of Iceland, including submarine events. After S. Thorarinsson. Courtesy of Museum of Natural History, Iceland.

74. 1783--Unnamed volcano, Iceland

A submarine eruption took place at 67°10'N, 15°W (?), which--allegedly--created a new island of temporary character (Berninghausen 1964). Great ash fall at sea was observed to the north and northwest of Iceland. The event was a member of the volcanic series previously mentioned.

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75. 1783--Unnamed volcano, Iceland

Another underwater eruption took place at 66°15'N (?), 18°30'W (?). A temporary island was formed (Berninghausen 1964).

⊼ ↑ ✯

76. 1788 July 22 (or July 27)--St. Augustine (?), Alaska

According to Sapper (1927) a submarine eruption might have taken place--but this is not certain. Cox et al. (1976) are of the opinion that the tsunami observed at this time was either due to the eruption of St. Augustine or to an unknown phenomenon that occurred on the continental shelf. Thus the volcanic origin of the seismic sea waves is doubtful.

⊼ ? ≌

77. 1790 November (?)--Kilauea, Hawaii

This eruption was accompanied by a base surge that killed many of the natives (Swanson and Christiansen 1976).

1792 April 1--Probably erroneous date. See: 1792 May 21.

1792 May 1--Probably erroneous date. See: 1792 May 21.

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78. 1792 May 21--Unzen, Kyusyu

The activity started on 1797 November 13 with earthquakes, rumblings, and avalanches. On 1792 February 10 rock fragments were thrown out. On March 1 the summit eruption stopped and lava began to flow. On March 5 a landslide occurred. On April 21 about 300 shocks were felt. On May 21 an earthquake with a magnitude of 6.4 on the Richter scale occurred at 32°18'N, 130°18'E, (Usami 1966). Note that the coordinates of the volcano are 32°45'N, 130°18'E. Also on this day, the eastern part of Maye-yama (a cone on the northeast, near the shore of the sea) collapsed and caused an avalanche toward the eastern foot, causing more than 15,000 casualties. A tsunami was produced by this avalanche and killed 4,300 persons on the coast. The avalanche itself, totaling 0.48 km^3, was either caused by an explosion at Maye-yama or by the earthquake mentioned above (Kuno 1962). Note: For the same event Heck (1947) gave 1792 April 1 and Iida et al. (1972) gave 1792 May 1. Although these dates are considered erroneous, both sources mentioned the

tsunami itself. The maximum height of the waves was 9 m and the tsunami magnitude is assigned as 2.5 (Iida et al. 1972).

? ? O ↑

79. 1792--Unimak, Aleutian Islands

A tsunami is mentioned by Cox et al. (1976) and is attributed to an earthquake and a volcanic eruption on Unimak Island (Pogrumnoi?). There are, however, no data about eruption of this volcano or other volcanoes on Unimak Island from this year (Latter 1979, Hantke 1979, Shackelford 1980). In the Aleutian-Alaska belt as a whole the following volcanoes showed activity in 1792: Goreloi, Great Sitkin, Makushin, Cerberus, and Semisopochnoi, respectively. If the tsunami is attributed to the eruption of a volcano on Unimak Island, the volcano in question is unknown. Note: the alleged tsunami is not mentioned by Iida et al. (1972); therefore, both the eruption and the seismic sea wave are doubtful.

? ↑ ?

80. 1795--Nameless submarine eruption site southeast of Unalaska, Aleutian Islands

Mentioned by Sapper (1927). No further information is available; therefore, the event is doubtful. Note: In the same year a very fearful, paroxysmal eruption, accompanied by a jokulhlaup (glacier burst) originated at Pogrumnoi volcano on Unimak Island (Mercalli 1907, Sapper 1927, Latter 1979).

⊼ ?

81. 1796 May--Bogoslof, Aleutian Islands

A violent ash eruption, earthquakes, and the birth of Joanna Bogoslova (also known as Ioann Bogoslof or Old Bogoslof or Castle Rock) occurred (Latter 1979).

⊼ ↑

82. 1800 June 24 - 25--Unnamed submarine volcano, Azores

The supposedly linear submarine volcano is located at 38°30'N, 27°25'W. Vapor jets were seen on June 25. The first earthquakes were felt on June 24 and the series of shocks continued to July 4 (Neumann van Padang et al. 1967).

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83. 1804--Bogoslof, Aleutian Islands

Castle Rock originated in May 1796 and rose until about 1804 (Latter 1979). It was not destroyed in 1804; only its growth ended then.

84. 1805--Near Unmak Island, Aleutian Islands

An outbreak--probably an eruptive phase of Bogoslof--took place in this year (Mercalli 1907). No further data are available; coordinates were not given by Mercalli.

⊼ ?

85. 1806--Bogoslof, Aleutian Islands

Lava erupted on the northern side of Castle Rock and flowed into the sea (Latter 1979). Castle Rock began to rise again perhaps during this year and continued until about 1820.

⊼

86. 1811 February 1 - 8--Unnamed submarine volcano, Azores

Approximate position: 37°52'N, 25°43'W. Submarine explosions, no further data (Neumann van Padang et al. 1967).

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87. 1811 June 14 - 22--Unnamed submarine volcano, Azores

The position of this volcano is the same as the one in item 86. An ephemeral island--named Sabrina--came into being, having had a height of 100 m and a diameter of 600 m. The dates in the Catalogue (Neumann van Padang et al. 1967) are contradictory; according to the text the island was born in July but the list takes it back to June. The latter was accepted, because this is mentioned by another catalogue as well (Neumann van Padang 1938)

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88. 1813 or 1814--Kona Coast, Hawaii

A tsunami was observed, but the generating area is unknown (Iida et al. 1972, Pararas-Carayannis and Calebaugh 1977). Note: As the Kona Coast is the western part of Hawaii, the direction is favorable for a tsunami that originated along the Japan-Kuril-Kamchatka arc. Lamb (1970) mentioned a submarine eruption near Kamchatka in 1814 between the latitudes 50° and 60° N and longitudes 156° and 163° E. Such a submarine outbreak can generate a tsunami; therefore, a volcanic origin for the seismic sea wave observed along the Kona Coast is not impossible. However, the correlation is doubtful.

⊼ ?

89. 1814 March 9--Raoul Island, Kermadec Volcanic Group

Submarine explosion in Denham Bay. A new island came into being that, in May, was almost 5 km in circumference. It disappeared in 1854 (Richard 1962).

⊼ ↑

90. 1814--Bogoslof, Aleutian Islands

An eruption has been noted (Latter 1979).

91. 1814--Nameless volcano near Unalaska Island, Aleutian Islands

According to Mercalli (1907), a new volcanic cone (island) was built up from loose materials and it was soon destroyed by the sea waves in the Bogoslof group. Whether the eruptions mentioned in items 90 and 91 are the same or not is not clear. We regarded them as two independent events.

92. 1815 April 5 - 12--Tambora, Lesser Sunda Islands

This eruption was one of the greatest volcanic catastrophes in history. It killed 92,000 people; some died from the eruption and the tsunami, and some died later from starvation and epidemics.

The activity started as early as 1812 with rumblings and the emergence of dense clouds. The new cycle of activity began on 1815 April 5, with strong detonations and heavy ash fall. The paroxysm (Plinian phase) took place between April 10 and 12. As a consequence, a caldera of collapse origin has been formed. The volume of the ejecta was estimated variously by authors; Neumann van Padang (personal communication) is of the opinion that about 30 km^3 may be the real value. During the paroxysmal phase, extraordinarily strong tornadoes were formed (Lane 1966). Note: The eruption magnitude was calculated to be 10.10 and the corresponding thermal energy 1.44×10^{27} ergs (Hedervari 1963), but these values were calculated using a conjectured value (86 km^3) for the ejecta. In the cited paper there was a printed error: 150 km^3 instead of 86. Accepting 30 km^3 as the real value, we calculate the thermal energy as follows:

$E_e = V\ r\ T\ q\ J$
(Yokoyama 1956-1957)

where E_e is the released total thermal energy; $V = 30 \times 10^{15}\ cm^3$, the volume of ejecta; $r = 2.0\ g/cm^3$, the mean density of it; $T = 800°C$, the mean temperature of the solid ejecta; $q = 0.25\ cal/g°C$, the specific heat of lava; and $J = 4.1855 \times 10^7$ ergs/cal, the equivalent work of heat. Substituting these values,

$$E_e = 5.02 \times 10^{26} \text{ ergs}.$$

The corresponding eruption magnitude is now 9.81. The tsunami magnitude is assigned as 2.0? (with a maximum height of 3.6 at Sumbawa and Amboina, Iida et al. 1972), and this corresponds to an energy of about 4×10^{22} which is a very small part of the released thermal energy and even that of the explosive energy, which might have been about 1 percent of E_e. Thus the island subsided 5-6 m.

Although April 4 and April 11 were also mentioned as the probable dates of the tsunami, generally April 10 is accepted (Heck 1947, Berninghausen 1969, Iida et al. 1972). The eruption was also accompanied by an earthquake.

93. 1815--Pribilof Isles, Bering Sea

Northeast of St. George a submarine eruption occurred at approximately 56°41'N, 169°07'W (Sapper 1927, Latter 1979).

94. 1816 December 8--Unnamed submarine volcano, equatorial Atlantic

A "bank" was seen at 0°32'S, 17°46'W. It extended almost 5 km in an east-west direction and 1.6 km in a north-south direction (Neumann van Padang et al. 1967).

95. 1818 November 8--Semeru, Java

Eruption from the central crater and explosions characterized the first known activity of this volcano (Neumann van Padang 1951). On the same day a great tectonic earthquake was felt all over Java that was very severe on the eastern part of this island. A tsunami was also observed in the Straits of Bali (Visser 1922). In all likelihood the earthquake triggered both the tsunami and the eruption; thus the outbreak and the seismic sea wave were indirectly related to one another. It is noteworthy, furthermore, that Guntur volcano had erupted a few days prior to these events, namely on 1818 October 21. Its activity ended on 1818 October 24.

96. 1819--Assongsong, Izu-Mariana Islands

A tsunami of magnitude 1 was observed at Asuncion, Mariana Island. Heck as well as Iida and others attribute it to a probable eruption of the volcano mentioned (Heck 1947, Iida et al. 1972). The eruption, however, has been questioned (Kuno 1962).

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97. 1820--Bogoslof, Aleutian Islands

Either a new eruption or only simple fumarolic activity occurred. The growth of Castle Rock probably ended in this year (Latter 1979).

98. 1823 February - July--Kilauea, Hawaii

Kilauea erupted from the southwest rift zone, accompanied by a submarine lava flow of about 2.3 $10^6\ m^3$. In June (or July?) a collapse occurred in the Kilauea caldera (MacDonald 1955).

99. 1824 May 1--Unnamed submarine volcano, equatorial Atlantic

The submarine eruption at 7°N, 21°50'W was supposed on the basis of hissing noise and bubblings of the water, which resembled the ebullition of boiling water. As regards the location of the event there are different opinions (for details see Neumann van Padang et al. 1967), but the eruption itself is regarded as certain.

100. 1825 September 6--Avachinsky, Kamchatka

There was a submarine eruption and a new island was formed (Richard 1962).

101. 1827 August 9 (or August 10)--Avachinsky, Kamchatka

Iida et al. (1972) have mentioned a tsunami of magnitude 1 that, according to their opinion, might be related to an eruption of the volcano mentioned. Vlodavetz and Piip (1959) have described an outbreak from the central crater of Avachinsky, accompanied by lava flow and lahar on June 27-29 but they gave no data for August 9 or 10. It may be that the difference in the dates is due to the application of the old and the new calendars. An earthquake (of tectonic origin) was also reported on August 9.

102. 1827--Unimak, Aleutian Islands

According to Heck (1947), a tidal wave was observed at Chernabura Island that was associated with an earthquake and the outbreak of a volcano on Unimak Island. The event is questioned by Iida et al. (1972): Was it really an eruption on Unimak, or was it confused with the August 9-10 tsunami, that was caused by Avachinsky (see item 101)? On Unimak Island there are the following volcanoes: Pogrumnoi, Westdahl, Fisher, Shishaldin, Isanotski, and Roundtop, respectively. Of these, Pogrumnoi was intensely active in the period 1827-1829, and Shishaldin had an explosive outbreak in January 1827 (Latter 1979). Or may it be that the activity of Shishaldin and Pogrumnoi were confused with one another by the observers?

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103. 1830 March 11 - May--Eldey, Iceland

Submarine explosions and smoke were observed rising from the sea about 4 km off Eldey (Berninghausen 1964).

104. 1831 June 28--Giulia Ferdinandeo Bank (or Graham Island), (Phlegraean Fields of the) Sicily Sea

The start of the underwater eruption was felt on a ship that was crossing the area in question. At the same time earthquakes were felt on the west coast of Sicily (Bullard 1968).

105. 1831 June - July--Giulia Ferdinandeo Bank, Sicily Sea

The following data in the Catalogue of Active Volcanoes (Imbo 1965) are not in exact congruence with that of Bullard (1968). For Bullard's data, see: 1831 June 28, July 10, July 18, July (end of the month), August 4, August, September 3 and 10, respectively. According to Imbo (1965), the new island reached a height of 65 m above sea level. At the end of the outburst the perimeter was 3,700 m. The island disappeared in late 1831. According to Neumann van Padang (1938), the activity started on 1831 June 12 and lasted until July 25. The diameter of the island was about 1,200 m.

106. 1831 July 10--Giulia Ferdinandeo Bank, Sicily Sea

A column of water about 18 m high was seen rising from the sea like a waterspout. It had a circumference of about 700 m and was followed by dense steam clouds that rose to a height of some 540 m (Bullard 1968).

107. 1831 July 18--Giulia Ferdinandeo Bank, Sicily Sea

A small island was found that was only about 3.6 m high and had a crater from which volcanic debris and a high column of vapor were ejected. The sea around this islet was covered with many dead fishes and floating cinders (Bullard 1968).

108. 1831 July (end of the month)--Giulia Ferdinandeo Bank, Sicily Sea

The eruption continued with great violence to the end of July, when the new island was 15-27 m high and had a circumference of some 1900 m (Bullard 1968).

109. 1831 August 4--Giulia Ferdinandeo Bank, Sicily Sea

The new island has reached the height of 60 m and was about 5,800 m in circumference. This was the maximum height, and thereafter the island began to diminish in size (Bullard 1968).

110. 1831 August--Giulia Ferdinandeo Bank, Sicily Sea

During this month there was violent agitation of the sea at the southwest side of the new island that caused dense white columns of steam to be emitted, which suggests the existence of a second vent under the sea (Bullard 1968).

111. 1831 September 3--Giulia Ferdinandeo Bank, Sicily Sea

The new island was 32 m high at most and had a circumference of some 960 m (Bullard 1968).

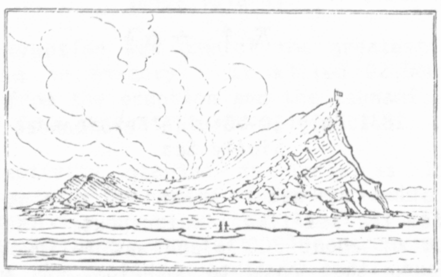

Figure 111/1.-- Graham Island on Sept. 29, 1831. Sketch by M. Joinville. Courtesy of Museum of Natural History, Iceland.

112. 1831 October--Giulia Ferdinandeo Bank, Sicily Sea

At the end of this month the new island was destroyed by the action of sea waves. Only a small mound of scoria marked the site. The rocky mass was composed of lava that had solidified in the throat of the submarine volcano. According to Bullard, if such a remnant was exposed on land it would be a volcanic neck (Bullard 1968).

113. 1833 March 10--Atitlan (?), Guatemala

A tsunami of magnitude 1 was reported on March 10 (Iida et al. 1972), and Lamb (1979) has mentioned an eruption of Atitlan volcano in this year. The relationship between these events is, however, very questionable because we have no further data about the outburst--e.g., the month and day are unknown. Can it be that this eruption was confused with the activity of Atitlan in the year 1837?

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114. 1835 February 20--Minchinmavida, Osorno, and Corcovado, Chile

The events that took place on this day represent one of the most interesting cases regarding the physical relationship between earthquakes, tsunamis, and volcanic eruptions.

The principal seismic event was a very great (M > 8.0) tectonic earthquake in southern Chile, near Concepcion, Valdivia, and Chiloe. The last earthquake of similar magnitude had taken place on November 19, 1822 and touched about the same area. Its epicenter was near Valparaiso, and the epicenter of the 1835 shock was situated somewhat southward of this point. In the following we shall try to establish the position of the 1835 epicenter--which can be regarded as the source area of the big tsunami as well--using the description of the earthquake given by Darwin (1957).

In the case of both earthquakes mentioned, elevations of the coast were experienced: In 1822 the coast was raised by 1 to 2 m for about 150 km in length; in 1835 the elevation reached 2.7 m (Iida et al. 1972) and even 3 m at Santa Maria Island (Darwin 1957). In the course of the next great earthquake of the same area, with an epicenter near Valdivia, on 1837 November 7, the reported uplift was of the same order (Richter 1958). On 1836 July 3, another strong shock took place in Chile but in the northern part of the country, probably near Antofagasta. No data are available for crustal deformations on the mainland in association with this earthquake. It is noteworthy,

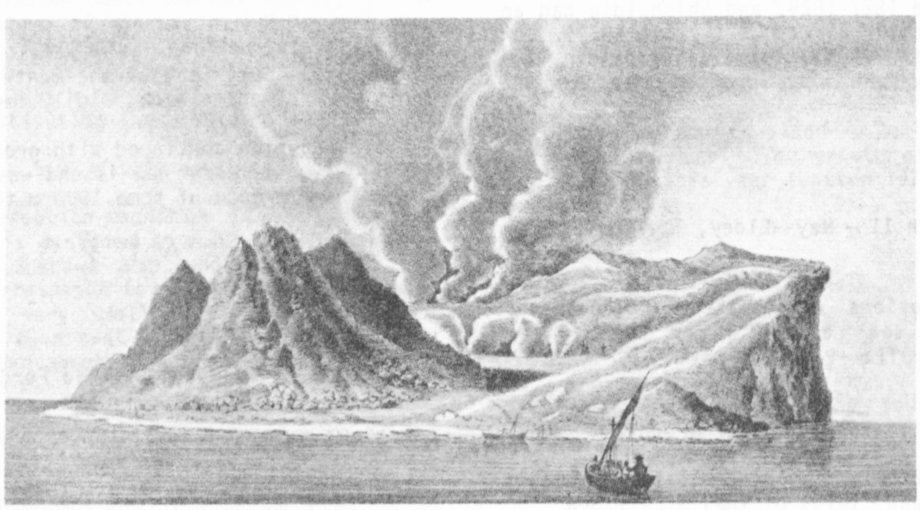

Figure 110/1.-- Graham Island, or Giulia Ferdinandeo Bank on August 25, 1831. After Mercalli.

however, that uplift of the coastal parts and of the belt between the axis of the oceanic trench and the shoreline is a frequent phenomenon in Chile; remarkable uplifts were observed, for example, as a result of the great earthquake sequence in 1960 as well. The pattern of the deformation was similar in each observed case. Such sudden deformations are the consequences of the shallow ($h \lesssim 70$ km) shocks. The earthquakes of the years of 1822, 1835, 1836, and 1960 were accompanied by tsunamis, which are also the results (almost exclusively) of shallow shocks that occur when sudden, more or less vertical displacements occur on the ocean bottom.

According to Davison (1936), the 1835 earthquake has been felt over a very large area, namely from the town of Mendoza to the Juan Fernandez Islands and from Chiloe Island to Copiapo. This is an elliptical area, the center of which in all likelihood lies near the real epicenter and can be found near the common boundary of the Pacific Plate and the South American Plate, by and large at the southernmost tip of the trench-like ocean deep.

There were three (or four?) great seismic sea waves, followed by numerous smaller ones. Three waves swept Concepcion. The first was 8.4 m in height, the others were still higher. At Talcahuano Bay--the port of Concepcion--the water reached an altitude of 15 m and ships sunk here. The tsunami magnitude was estimated to be about 3 (Iida et al. 1972), and the corresponding energy was 1.6×10^{23} ergs. According to Kausel (1965), the Richter magnitude of the principal shock might have been 8.4-8.6 (our calculations give 8.2, see later), which means a total energy of 25.1×10^{23} - 50.1×10^{23} ergs.

The tsunami waves were observed as far away as Hawaii, and moderate damage was reported from Kauai. The average velocity of the waves in the open ocean might exceed 650 km/hr, depending on the depth of the water.

It is worthwhile to mention that Sapper (1927) has attributed the seismic sea waves to a submarine eruption at the Juan Fernandez Islands (see next item). This opinion must be rejected, because this tsunami was without any doubt of seismic origin and similar phenomena were frequently observed in other times along the Chilean coast without any submarine outbreak.

Darwin (1957) has written a dramatic account of the great earthquake of 1835 that is based for the most part on his own experiences (it happened that he had been in Valdivia at the time of the shock). According to his account (see Adams 1964) the principal shock occurred at half-past eleven o'clock in the forenoon of February 20 and the shaking of the ground lasted for about 2 minutes.* In Concepcion and

*Concerning the time of occurrence and the time sequence of the main events we have somewhat differing data as follows:

Event	Local time of occurrence (start)			Tract of time in minutes	
	Iida et al. (1972)	Davison (1936)	Darwin (1957)	Davison (1936)	Darwin (1957)
First shock		11 hr 40 min	0.5	≅0.5	
Second principal shock	11 hr 26 min	11 hr 41 min or 11 hr 41.5 min	11 hr 30 min	2	2
Final vibrations				1.5	
First tsunami	11 hr 30 min (arrival)				
Second tsunami	≅ 11 hr 40 min (arrival)				

The time of 11 hr 30 min probably means the arrival of the first wave at Santa Maria Island and 11 hr 40 min is probably the arrival of the second wave at Talcahuano. According to Davison, 15 min after the earthquake (which--the first or second shock?) the sea retreated about a mile from the coast of Talcahuano. According to Davison, 15 min after the earthquake (which--the first or second shock?) the sea retreated about a mile from the coast of Talcahuano. After an equal interval a great wave came very slowly through the passage between Qiriquina Island and the mainland. In a few minutes a second larger wave swept in, and after it a third and still larger one arrived. All the later sea waves decreased in height, but for 3 days following the shock the water ebbed and flowed irregularly--2 or 3 times an hour. For the calculations, we accepted Iida's data.

Talcahuano all the houses were partly or perfectly destroyed and the ruins of Talcahuano were totally washed away by the seismic sea waves. In addition, 70 villages were demolished. There were large and wide ruptures in many places in the soil, with a trend of NS or NW-SE. Their width reached 1 m. Numerous aftershocks were felt that number at least 300 during the first 12 days.

In Concepcion the position of the ruins suggests that the shock came from the southwest. The sound of the rumbling came from the same direction. On the tiny Santa Maria Island--which lies southwest of Concepcion at a distance of about 50 km--the elevation of the coast amounted to 3 m, but near Concepcion the elevation was as small as 0.6-0.9 m only. From these facts one concludes that the epicenter of the main shock might have been situated southwest of Concepcion, and thus south or southeast of the center of the ellipse of perceptibility. It should be added that the earthquake in question was almost certainly of shallow origin. We know only very few examples in which intermediate shocks (h = 71-300 km) are followed by tsunamis, although some examples--particularly those near Greece--are mentioned in our present volume. Deep (h >300 km) earthquakes are never accompanied by seismic sea waves. On the other hand, for the generation of a tsunami, dip-slip faulting is needed (Bolt et al. 1975); that is, dip-slip displacement must occur within the hypocenter in the moment of the sudden release of the stored seismic energy. Strike-slip displacements are never accompanied by seismic sea waves.

Let us now consider the fact that within the oceanic trenches, the first motions have a tensional character; that is, not dip-slip (Stauder 1968). Owing to the subduction process, dip-slip earthquake mechanisms are to be expected within the belt lying between the continentalward slope of the trench and the volcanic chain that is usually parallel to the strike of the oceanic trench. In case of such a displacement in the depth, uplift must occur along the oceanic shore, as was frequently observed in Chile after great earthquakes.

Taking into account all the evidence summarized above, and--furthermore--considering that the real epicenter must be near the center of the area of perceptibility, we come to the conclusion that the most probable site of the epicenter of the main shock in the year of 1835 was a little southwest of Santa Maria Island but by no means within the deep oceanic trench or beyond (oceanward of) it. The epicenter most likely was between the continentalward slope of the trench and the seashore.

We have already mentioned (see footnote) that, according to the data of Iida et al. (1972), the first tsunami has reached the coast of Santa Maria Island within a very short time--only about 4 min after the occurrence of the main shock. Using a depth contour map of the area southwest of Concepcion, we found that the median depth of the ocean water within the first kilometer distance measured from the southwestern point of Santa Maria in the direction of the southwest is only about 4 m. Taking the first two km distances together, we calculate an average depth of some 8.5 m. The velocity of propagation of tsunami waves can be expressed by the formula:

$$v = (gH)^{1/2},$$

where g is the acceleration due to gravity (9.8 m s^{-2}) and H the average depth of the water. Substituting now the value of H = 8.5 m, we get v = 9.1 m s^{-1}. Accepting that the wave arrived during 240 s from the source to the southwestern shore of the island and its median velocity was 9.1 m s^{-1}, we find that the source might have been at a distance of about 2.2 km from the edge of the island, and--considering Darwin's account on the direction--in the southwest, looking from the shore of the island. Thus the approximate coordinates of the epicenter that can be regarded to be identical with the source of the tsunami, are 37°00'S, 73°40'W. This deduced location agrees with one that has been suggested by the Seismological Institute of Santiago (Kausel 1965), namely: 36.5°S, 73.0°W. The distance between these two points is not more than 130 km.

We have the opportunity to further investigate the physical parameters of this great earthquake. Iida (1958, 1961) has pointed out that the following equation is valid for the relationship between earthquake magnitude and tsunami magnitude:

$$m = 2.61\ M - 18.44,$$

where M is the Richter magnitude and m the tsunami magnitude. For the principal tsunami that is treated here m = 3 can be accepted (Iida et al. 1972). Hence M = 8.21. Using this value we can calculate the length of the front line of the tsunami, L:

$$\log L = 0.5\ M - 1.8,$$

from which L = 201.8 km. According to Iida (1958, 1961), for the focal depth the following expression can be used:

$$M \geq 7.75 + 0.008\ h,$$

if the tsunami had a devastating force. From here the focal depth h $\leq$ 57.5 km. Summarizing and rounding the values received, we can accept 8.2 for M, 200 km for L, and 55-60 km for h.

On the day of the earthquake three subaerial volcanoes and a submarine one as well began to erupt. For information about the submarine explosion, see the next item. According to Symons (1888) and Lamb (1970) the subaerial volcanoes were as follows: (a) Minchinmavida; (b) Osorno; and (c) Corcovado. Previous eruptions of these volcanoes were as follows:

(a) 1742; 1834 November;
(b) 1790 March 9-1791 December; 1834 November 29;
(c) 1834 November; no data are available about the activity of this volcano prior to 1834 (Casertano 1963, 1963a).

It is also interesting to note that all these volcanoes had been active prior to the great earthquake again simultaneously, namely in November 1834. According to Davison (1936) from 1834 January 1 to 1835 February 20 they were active; that is, until the day of the great earthquake, some shocks were felt in the Concepcion area, all feeble with the exception of one at the close of October 1834. It can be supposed that the three simultaneous eruptions in November 1834 were initiated (triggered) by this strong shock in October, the magnitude of which is unknown.

Furthermore, it appears that on the day of the 1835 February 20 earthquake these three volcanoes were again directly triggered by the shock (Hedervari

1979). On the other hand, the tsunamis were also initiated by the earthquake. Thus the eruptions were indirectly correlated with the seismic sea waves; that is, the tsunamis were not of volcanic, but of tectonic origin--contrary to the opinion of Sapper, as already mentioned.

115. 1835 February 20--Submarine eruption in the group of Juan Fernandez Islands

Earlier activity from this place is not known. The outbreak was accompanied by explosions, dense columns of smoke that issued from the ocean, and "flames" that illuminated the whole island (Richard 1962). This eruption was probably also triggered by the great Chilean shock on the same day (Hedervari 1979), and thus it was also indirectly associated with the tsunamis as well. The coordinates of the eruption are 33°37'S, 78°47'W. Note: This unnamed underwater volcano was also mentioned by MacDonald (1972), who also indicated the occurrence of the seismic sea waves.

116. 1835 April 23 - 26--Banua Wuhu, Sangihe Islands

A 90-m high temporary island was created by submarine activity. In 1848 only a few rocks remained (Neumann van Padang 1941).

117. 1836 January 25--Unnamed submarine volcano, equatorial Atlantic

Location: 0°40'S, 20°10'W, approximately. A seaquake, lasting about 3 min, was observed at 9 o'clock in the evening. Black volcanic ash was collected at 0°35'S, 15°50'W (Neumann van Padang et al. 1967).

118. 1838--Nameless submarine volcano, Iceland

Location: 66°15'N (?), 18°55'W (?). A little doubtful (Berninghausen 1964).

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119. 1839 February 12 - 13--Nameless submarine volcanic center, Islas Juan Fernandez

Location: 33°34'-40'S, 76°49'-51'W. Supposedly, although not yet proved exactly, an ephemeral island probably of conical shape came into being. It was a rather large island, namely almost 5 km wide and a little less than 10 km in length. It appeared approximately at the summit of the most easterly seamount in the vicinity of Islas Juan Fernandez (Richard 1962). Note: This alleged island is not indicated in Andrees' great "Handatlas" (which was published in 1903).

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120. 1840 January 4--Merapi, Java

A great earthquake was felt from Banjoemas to Kediri, Java, and a tsunami was observed at Patjitan (Visser 1922). Note: These events took place on January 4. Banjoemas can be found in central Java, west of Merapi volcano; Patjitan is situated a little southeast of Merapi; and Kediri is east of Merapi. The Banjoemas-Merapi distance is almost equal to the distance between Merapi and Kediri. Thus it can be supposed that the epicenter was very near Merapi volcano and the shock directly triggered the volcano eruption. The day of the commencement of the eruption is not known, but the event took place in January. Therefore it seems to be a reasonable supposition that the tsunami and the eruption were indirectly correlated with one another. The tsunami is not mentioned by Iida et al. (1972), nor by Heck (1947).

121. 1840 May 30--Kilauea, Hawaii

An eruption took place from the east rift zone, accompanied by a submarine lava flow approximately 153 million m^3 (MacDonald 1955). After this event, probably in June, a collapse of the Kilauea caldera was noted.

122. 1843 February 17--Nameless submarine volcano near Marie Galante, West Indies

In the Catalogue of Active Volcanoes (Robson and Tomblin 1966) there is a printer's error: The earthquake took place on 1843 February 8 and not on 1943 February 8. The shock in question reached 9° on the 12° scale of intensity. It occurred at Guadeloupe. A tsunami of a height of 1.2 m was observed as well as an interesting earthquake-fountain: Columns of water some 30 m high were ejected from fissures in the ground (Robson 1964). Note: This shock was, without any doubt, the triggering one for the submarine eruption that took place approximately half way between Guadeloupe and the eastern part of Maria Galante. A large column of black water rose in a succession of jets, and steam was emitted around the column at the sea surface. The outburst lasted for about half an hour only (Robson and Tomblin 1966). The coordinates of the volcano are 15°08'N, 61°17'W (approximate values). It must be noted that the latitude was erroneously printed in the Catalogue of Active Volcanoes as 16°08'N instead of 15°08'N, and this error was repeated by MacDonald (1972) as well.

123. 1843 July--Near Arakan, Indian Ocean

Neumann van Padang (1938) has reported the birth of a new island at 18°N, 93°30'E, near the shore of Arakan, Bay of Bengal, Indian Ocean.*

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124. 1845 June 18--Madrepore Bank (Phlegraean Fields of) Sicily Sea

Emissions of sulfurous gases were noted and an earthquake was felt (Imgo 1965), which may suggest a submarine outbreak. The event, however, is questionable.

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125. 1846 October 4 - 5--Pinne Marine Bank, Sicily Sea

An eruption occurred with ejection of internally incandescent fragments of volcanic material (Imbo 1965).

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126. 1850--Nameless submarine volcano between Taiwan and the Mariana Islands

The location of the event was 20°56'N, 134°45'E. The outbreak caused a sudden commotion of the water, a rise of air temperature, and a smell of sulfur (Kuno 1962).

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127. 1850--Unnamed submarine eruptive center west of Ibugos, Islands North of Luzon, Philippine Islands

Location: 20°20'N, 121°45'E. The eruption is doubtful, and no details are available (Neumann van Padang 1953).

⊼ ?

128. 1851 - 1852--Metis Shoal, Tonga Volcanic Group

Smoke had been seen in 1851 and in 1852. A submarine eruption was reported (Richard 1962).

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*The 1843 July eruption of near Arakan, Indian Ocean, as well as some further reported submarine outbursts, namely on 1881 December 31 and 1906 December 15 (lasted probably until December 31), when a new island was formed, and those in 1908 (another new island came into being then) and 1914, were of mud-volcanic manifestations and not igneous volcanic ones (Sapper 1927, van Padang 1938). Disregarding these examples, mud-volcanoes generally are not treated in our Catalogue.

129. 1852 July 17--Unnamed submarine volcano, equatorial Atlantic

Latitude: 3°30'S, longitude: 24°30'W. A seaquake was observed. The water appeared to be agitated as if it had boiled. Water vapor rose. "A submarine volcano conceivably was active with such a violence that a column of water of more than 5,000 m was heated? Because of the great depth, however, this account probably should be considered questionable" (Neumann van Padang et al. 1967, p. 123).

⊼ ?

130. 1852 September 14--Nameless submarine eruptive center, southern Atlantic

White vapors and vaulting of the sea surface have been seen. Sapper doubted that this event was of volcanic origin (Neumann van Padang et al. 1967).

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131. 1852 November 26--Banda Api (?), Banda Sea

According to Heck (1947) an almost 8-m high wave reached Amboina. The tsunami with a magnitude of about 2 was observed in the Moluccas, and the generating area was in the Banda Sea (Iida et al. 1972). Lamb (1970), on the basis of Russel (1888) has reported an eruption in the Moluccas and assigned it to Gunung Api, which is located at 6°35.5'S, 126°39'E. But the coordinates of the volcano in Lamb's paper were as follows: 4.5°S, 130°E. These coordinates, however, give the location data of another volcano, namely Banda Api (4°31'E, 129°52'E, see: Neumann van Padang 1951). But neither Neumann van Padang nor Sapper (1927) have mentioned any eruption of Banda Api and Gunung Api in the year of 1852. Therefore the volcanic nature of the tsunami is more than doubtful.

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132. 1852--Home Reef, Tonga Volcanic Group

Submarine activity and the appearance of a new island are reported (Richard 1962).

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133. 1853 October 29 - 1854 January--Submarine volcano near the eastern coast of Taiwan

Position: 24°N, 121°50'E. Underwater activity has been reported, accompanied by ash and smoke. The sea was strongly agitated (Kuno 1962). Note: In MacDonald's book (1972) there is a printed error concerning this volcano: namely, 1853-1954 is indicated instead of 1853-1854.

⊼ ↑

134. 1854 January 15--Submarine eruptive center, the location of which is very unclear

There are some errors and confusions concerning the exact place of this submarine eruption point. MacDonald (1972) gives 21°50'N, 121°11'E and mentions only the year. Sapper (1927) gives the date of

eruption as 1854 January 15 and 20°56'N for the latitude as well as 134°45'E for the longitude, which is the site of the volcano assigned as 8.1-1 in the Catalogue of Active Volcanoes (Kuno 1962). This place, however, does not coincide with Sapper's Plate XXXI, on which the eruption's point is given as 21°50'N, 121°11'E. This location is identical with the place of volcano 8.1-2 (Kuno 1962). In addition, an eruption is mentioned in the Catalogue of Active Volcanoes (Neumann van Padang 1953) for the same day in the case of volcano 7.4-5 that lies at 20°20'N, 121°45'E.

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135. 1854--Raoul Island, Kermadec Volcanic Group

The volcanic island that came into being in 1914 disappeared in 1854 (see item 89, Richard 1962).

136. 1856 March 2 - 17--Awu, Sangihe Islands

An explosive eruption from the central crater and a tsunami with a magnitude of about 1 were noted (Iida et al. 1972). The Celebes Sea or Molucca Passage (Heck 1947, Berninghausen 1969) was the generating area. The seismic sea wave occurred on March 3; the eruption lasted until March 17. It may be that the tsunami was caused by nuees ardentes entering the sea.

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137. 1856 July 22--Submarine eruption near Shaum Shu (Shumshu) Island, Kuril Volcanic Belt

In referring to Perrey, Mercalli (1907), has mentioned a submarine eruption at the northernmost end of the Kuril Volcanic Belt, just south of the southernmost tip of Kamchatka. According to Mercalli, a Russian ship, "Dwina," reported floating pumice at 50°53'N, 158°52'E. Note, however, that the longitude was measured from Paris and not from Greenwich. Their difference in longitude is 2°02'. Calculating on this basis, one finds that the probable location of the event was 50°53'N, 160°54'E, though Sapper (1927) gave 50°53'N, 161°12'E. The eruption is not mentioned in the Catalogue of Active Volcanoes of the World.

⊼

138. 1856 July 26--Submarine activity near Unimak Island, Aleutian Islands

Near southwest Unimak a gigantic water-column (base surge?) was first seen; later on smoke and "flames" were observed, and ash and lapilli were thrown from the water. At the same time swirling of the water was observed (Sapper 1927). According to Cox et al. (1976), a submarine eruption in the Unimak Strait was the cause of the agitation of the ocean and possibly a small tsunami followed the outbreak. Iida et al. (1972), however, doubted the tsunami and attributed the waves to a seaquake.

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139. 1856 September or October 10 - 1860 October(?) --Didicas Rocks, islands north of Luzon, Philippine Islands

A submarine eruption occurred here (van Bemmelen 1970). According to the Center for Short-Lived Phenomena (Report No. 506), "spines" were formed at first, and these were the subaerial expressions of a submarine volcanic edifice. Subsequent eruptions united these rocks into an islet now known as Didicas.

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140. 1856 September--O-sima, Izu-Mariana Islands (?)

A tsunami is indicated off the coast of O-sima (?) and the report is written with spelling Oshima. The location may be Osima-O-Sima off Hokkaido and Iburi, as given in Heck (1947), but Iida et al. (1972) are of the opinion that the generating area was the Tokyo Bay and the place of observation was Tokyo and its vicinity; according to their view it was a storm surge. Lamb (1970) has mentioned the eruption of a Japanese volcano in September 1856. The volcanic nature of the tsunami, however, is as doubtful as the seismic nature of the waves; we accept the view of Iida et al. (1972) and do not regard this event to be of geophysical origin.

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141. 1856 November 25--Unnamed submarine volcano, northern Atlantic

Ebullition of the water was noticed. The phenomenon, which was accompanied by rising hot fumes, lasted about half an hour. Note that another report gave 1857 as the year of occurrence of the event. It is considered that this eruption is questionable unless it occurred in the shallower water to the west. Perrey gave the following coordinates: 39°57'N, 25°50'W (Neumann van Padang et al. 1967).

⊼ ?

142. 1856--Onnimah Strait, near Cape Ommaney, northeastern Pacific

A submarine eruption was reported by the whaler "Alize Frazer" (Gutenberg and Richter 1954). Note: This event is rather uncertain, as the point 56.2°N, 134.7°W is very far from the volcanic belt.

⊼ ?

143. 1857 August 14--Unnamed submarine volcano near Cape of Good Hope

Sapper (1927) has mentioned a submarine outbreak at 36°30'S, 18°50'W, a point on the South Atlantic Ridge where a submarine eruption really is possible. However, his data for the longitude are clearly erroneous. The Catalogue of Active Volcanoes (Neumann van Padang et al. 1967) emphasizes that the point can be found at a distance of about 160 km off the Cape of Good Hope, and thus its coordinates are 36°30'S, 18°50'E. Here the depth of the ocean is 3,655 m and observation of a submarine outbreak is not likely. On the other hand, this is not a volcanic area. The real

cause of the phenomenon (the sea suddenly became restless) was a strong seaquake and not an eruption (Neumann van Padang et al. 1967).

⊼ ? ?

144. 1857--Camiguin de Babuyanes, islands north of Luzon, Philippine Islands

A temporary island came into existence (van Bemmelen 1970). Eruption from a parasitic crater under the sea level and phreatic explosions occurred (Neumann van Padang 1953).

⊼ ↑ ✶

145. 1857--Home Reef, Tonga Volcanic Group

This was probably a submarine eruption accompanied by the birth of a new island (Neumann van Padang et al. 1967).

⊼ ✶ ?

146. 1857--Unnamed submarine volcano, Azores

Sapper (1927) has mentioned an eruption at 39°57'N, 25°50'W. This event is not mentioned in the Catalogue of Active Volcanoes; therefore, it is doubtful.

⊼ ?

147. 1858--Metis Shoal, Tonga Volcanic Group

Submarine activity occurred that led to the formation of a new island. The rock in question was a little less than 9 m high (Richard 1962). It reached the height of 9 m in 1875 and in 1878 an island with a length of 180 m and a height of 35 m was found (Sapper 1927). The island was in a cloud of smoke.

⊼ ↑ ✶

148. 1859 January 23--Mauna Loa, Hawaii

Eruption was noted from the northern flank and submarine lava flows of about 229 million m^3 were observed (MacDonald 1955).

149. 1859 (?)--Submarine eruptive center, equatorial Atlantic

An outburst happened at 0°12'N (?), 19°W (Sapper 1927). It is not mentioned in the Catalogue of Active Volcanoes; therefore, the event is uncertain.

⊼ ?

150. 1860 April 21--Near the coast of Peru at San Lorenzo Island

After an earthquake, a submarine outbreak was observed. The event is uncertain (Sapper 1927). No data on exact location are available. It is only known that the earthquake happened at Calles.

⊼ ?

151. 1861 August--Near the coast of Peru between Coronel and Iquique

A new island was seen in the company of a mighty column of smoke. Sapper (1927) thought the event uncertain. No data is known about exact location, and the event is not mentioned in other sources.

⊼ ✶ ?

152. 1861 November--Unnamed volcano near Narage, Bismarck Archipelago

Van Bemmelen (1970) gave the following data for its location: 4°28'S, 149°E; but Sapper (1927) mentioned 4°33'S, 149°07'E. Water sprung up to 45 m. This is accepted as a real submarine volcanic eruption.

⊼

153. 1863 August 12--Giulia-Ferdinandeo Bank, Sicily Sea

A submarine eruption that led to the origin of a new, ephemeral island took place (Imbo 1965).

⊼ ✶

154. 1865 July 9--Unnamed submarine volcano, northern Atlantic

The eruption took place at 38°45'N, 38°05'W. Scoriae, probably pumice, reached the surface of the water, where it formed a "floating mountain." There was a strong smell of sulfur, and rumblings were heard. By mistake, Sapper placed this outburst in the year 1867 (Neumann van Padang et al. 1967).

⊼

155. 1865--Falcon Island, Tonga Volcanic Group

Submarine eruption, breaking reef (Richard 1962).

⊼

156. 1866 January 26 - 1870 October 15--Santorini, Aegean Sea

Long submarine activity occurred, in the course of which new islands have originated (for certain details see the following items as well). According to Sieberg the eruption commenced on 1866 February 1 and not on 1866 January 26. The former date is accepted by Galanopoulos (1960a) too, but the latter is mentioned by Georgalas (1962). There were three tectonic shocks in direct association with the start of the long eruption sequence. If the first day of the start of the activity was really 1866 February 1, the shock that occurred on 1866 January 31 can be regarded as the direct triggering earthquake, which initiated the eruption immediately (Hedervari 1979, Komlos et al. 1978). Note that the shock in question occurred

exactly underneath Santorini itself. The coordinates of the volcano are as follows: 36°24'13.31"N, 25°23'46.9"E (Georgalas 1962), whereas the epicenters of the three shocks mentioned were in the following locations:

1866 Jan. 31: 36°24'N, 25°18'E (I_0 = 7°),

1866 Feb. 2: 38°15'N, 26°15'E (I_0 = 8°),

1866 Feb. 6: 36° N, 23° E (I_0 = 8°),

where I_0 means the epicentral intensity in terms of the 12°-scale of Mercalli and Sieberg. All of these shocks were of shallow (h < 70 km) origin. The above data are from Galanopoulos (1960, 1960a), but Karnik (1971) has given 24°E instead of 23°E for the last item. The foreshock of the February 2 quake had taken place on 1866 January 19 (Galanopoulos 1960a). No data are available for a tsunami in association with the January 31 shock, but the other two were accompanied by seismic sea waves (Galanopoulos 1960, Ambraseys 1962). On February 2 a tsunami was observed in the Eastern Sporades, particularly at Chios with an intensity of III on the Sieberg-scale.* On February 6 another tsunami was observed along the southern coasts of Peloponnesus and Kythera Island, respectively, with an intensity of IV. At Avlemonas the water rose to a height of at least 8 m or more.

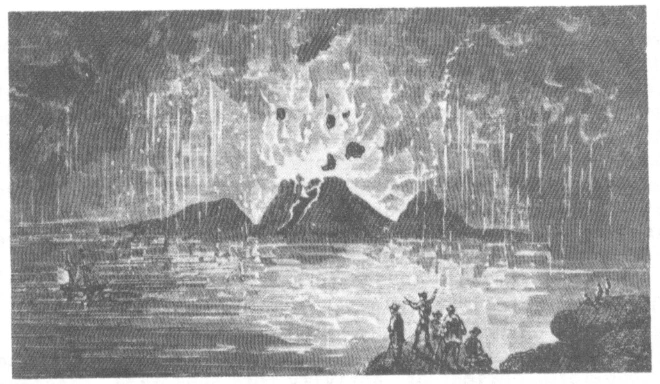

Figure 156/1.--Old engraving shows the 1866 eruption of Nea Kameni, Santorini. Height of central and right peaks is exaggerated (compare with fig. 156/2.

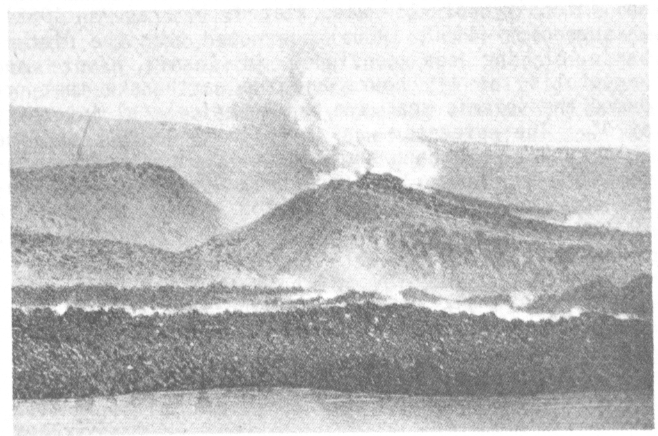

Figure 156/2.--A historically significant early photo (taken by P. Desgranges) of the eruption of Nea Kameni, Santorini, in 1866. The Georgios crater is active. After Mercalli.

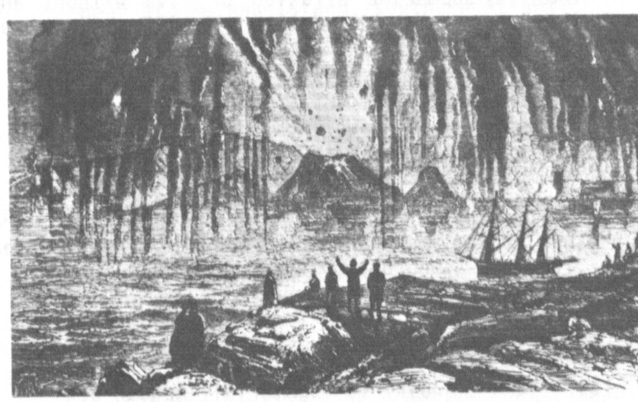

Figure 156/3.--Another old engraving of the eruption of Nea Kameni volcano, Santorini, in 1866.

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*This scale consists of six grades as follows (Ambraseys 1962, Karnik 1971):

I. Very light. Wave so weak as to be perceptible only on tide-gauge records.

II. Light. Wave noticed by those living along the shore and familiar with the sea. On very flat shores generally noticed.

III. Rather strong. Generally noticed. Flooding of gently sloping coasts. Light sailing vessels carried away on shore. Slight damage to light structures situated near the coast. In estuaries, reversal of the river flow for some distance upstream.

IV. Strong. Flooding of the shore to some depth. Light scouring on man-made ground. Embarkments and dikes damaged. Light structures near the coast damaged. Solid structures on the coast injured. Big sailing vessels and small ships drifted inland or carried out to sea. Coasts littered with floating debris.

V. Very strong. General flooding of the shore to some depth. Quay-walls and solid structures near the sea damaged. Light structures destroyed. Severe scouring of cultivated land and littering of the coast with floating items and sea animals. With the exception of big ships all other types of vessels carried inland or out to sea. Big bores in estuary rivers. Harbor works damaged. People drowned. Wave accompanied by strong roar.

VI. Disastrous. Partial or complete destruction of man-made structures for some distance from the shore. Flooding of coasts to great depth. Big ships severly damaged. Trees uprooted or broken. Many casualties.

The earthquakes mentioned might have been related to the eruption--crustal deformations led to the occurrence of the shocks, and the same deformations compressed the magma chamber of Santorini at a depth of a few kilometers from the surface, resulting in the commencment of the outbreak. The earthquakes caused the two tsunamis. Therefore it can be claimed that these seismic sea waves were indirectly correlated with the eruption. For the physical relationship between tectonic earthquakes and volcanic eruptions see Nakamura (1971, 1975), Komlos et al. (1978), Hedervari (1975, 1976, 1976a, 1976b, 1976c, 1977, 1977a, 1977b, 1978, 1979).

Note: It is remarkable that during the 1866-1870 period of activity of Santorini, another tsunami was also observed in the vicinity of this island-volcano, namely on 1867 September 20 at Crete, near Herakleion and along the south coast of Peloponnesus with an intensity of IV; furthermore in the region of the Ionian Islands with an intensity of III, and even along the southeast coast of Italy where an intensity of II was stated (Ambraseys 1962). Galanopoulos (1960, 1960a) has noted that the disturbance of the sea continued in Chania, Zante and Argostolis for 4½ hours and the earthquake that produced the seismic sea wave had an epicentral intensity of 9°. The epicenter was at 36°30'N, 22°15'E and the shock might have been an intermediate one. This statement is particularly interesting because--as was mentioned elsewhere in this catalog--intermediate (h > 70 km) earthquakes generally do not cause tsunamis.

157. 1866 February 4--Santorini, Aegean Sea

After a submarine effusion of lava without any explosive phenomena, the dome of Georgios appeared above the sea (Georgalas 1962).

158. 1866 February 12--Santorini, Aegean Sea

Explosions began within the caldera that were a prelude to the emergence of a new dome from the sea --see item 159--(Georgalas 1962).

159. 1866 February 13--Santorini, Aegean Sea

A new island, called Afroessa, originated west of Georgios Island in the interior of the caldera (Georgalas 1962).

160. 1866 March 10--Santorini, Aegean Sea

A very small island, called Reka, came into existence within the caldera. It had a diameter of some 35 m and a height of only 1.5 m. This dome was united with the lavas of Afroessa on 1866 March 4, but it was covered afterward by the lavas of Georgios Island (Georgalas 1962).

161. 1866 May--In the first part of the month, Santorini, Aegean Sea

A fourth volcanic center has probably been active for a short time within the caldera, but--according to some authors--this feature was due to a submarine lava flow from Afroessa, and thus it was not the consequence of the activity of a fourth, independent volcanic center (Georgalas 1962).

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162. 1866 May 17--Santorini, Aegean Sea

The lava flow of Afroessa stopped (Georgalas 1962).

163. 1866 June 17--Santorini, Aegean Sea

The lava dome, known as Afroessa, became perfectly quiet (Georgalas 1962).

164. 1866 September 12 - November (to the middle of the month). Unnamed submarine volcano near Olosega Island, Samoa Volcanic Group

There was explosive, underwater activity (Richard 1962). Coordinates of the event: 14°12'S, 169°36'W.

165. 1867 June 1 - 8--Santa Barbara (Terceira), Azores

A huge explosion occurred under the sea that emitted water jets, gases, and black cinder (Neumann van Padang et al. 1967).

166. 1867 October--Juan Fernandez Islands

After a seaquake many dead fishes appeared and the water became as white as snow at 34°55'S, 77°38'W. These phenomena suggest a submarine outburst; however, as the event is not mentioned in other sources we regard it as somewhat doubtful. The original data, cited above, are from Sapper (1927). The seaquake was not accompanied by a tsunami.

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167. 1867 (at the end of the year) and 1868 January --Unnamed submarine volcano, Iceland

There was definitely a submarine eruption off Tjornes, a short distance to the north of Manareyjar (Thorarinsson 1965). Berninghausen (1964) has noted a submarine outbreak in 1868 at 66°18'N (?), 17°08'W

(?), but it is not clear whether these two eruptions are identical or not.

168. 1867--Unnamed submarine volcano near the northern point of Taiwan, China Sea

A submarine eruption at 25°25'N, 122°20'E has been reported (Kuno 1962, MacDonald 1972). No further data are available.

169. 1868 March 27--Mauna Loa, Hawaii

Eruption from the southwest rift zone, accompanied by lava flows beneath the surface of the ocean has been noted. The volume of lava is estimated to be 76 million m^3 (MacDonald 1955).

170. 1868 April 2--Kilauea, Hawaii

An eruption from Kilauea Iki crater (east rift zone), an earthquake (M = 7.0-7.75), and a very great tsunami with a maximum height of 20 m were reported. Ebb and flow of the ocean was observed thirteen times, with a 7- or 8-min interval between each flow. A 15-min interval was noted at Honolulu. The village of Keauhou and the storehouse were swept away. Punaluu was also swept out of existence (Heck 1947). The tsunami magnitude was assigned as 4.1 (Iida et al. 1972), which corresponds to an energy of 7.2×10^{23} ergs, as calculated by the expression

$$\log E_{ts} = 21.4 + 0.6\ m,$$

where E_{ts} is the tsunami energy and m the magnitude (Iida 1958, 1961). Note that the seismic energy was 0.1995×10^{23} ergs if M = 7.0 or 2.661×10^{23} ergs if M = 7.75, calculated from the formula

$$\log E = 11.8 + 1.5\ M,$$

where E is the seismic energy and M the Richter magnitude. In both cases we calculate an energy smaller than that of the tsunami, which is physically impossible. Therefore we conclude that either the Richter magnitude of the shock was greater than 7.75, or the tsunami magnitude was smaller than 4.1. A third possibility is that a great mud-flow (lahar) descending into the sea on the southeast flank of Mauna Loa volcano created the tsunami (Pararas-Carayannis and Calebaugh 1977). The slip of the material involved was triggered by the earthquake. The shock, on the other hand, was probably related to an eruption of Mauna Loa that started 6 days earlier. The volume of the lava flow is estimated as 191,000 m^3 (MacDonald 1955) which represents a very small amount of thermal energy release, namely 0.07×10^{23} ergs (Hedervari 1963).

Concerning this devastating tsunami we have some additional data (Pararas-Carayannis et al. 1977). There was severe damage from Kahuku to Kapoho. The water receded horizontally 46 m. At south Puna and Kau, where the water rose to 18 m, the first wave was the most destructive, there were 108 houses destroyed, and 81 persons died. The coast of Puna and Kau subsided 2 m on the average, and small villages were submerged along the coast for 120 km. After the shock ended, the sea inundated inland areas and all buildings were swept away at Keauhou where the maximal elevation of the water reached 15 m. At Punaluu the 6-m high waves destroyed everything: stone church, wooden houses, and almost all of the coconut trees were washed down. The shoreline was rearranged because land was lost from the beach. Kawa Bay and Ninole were completely destroyed, and at Honuapo--where the waves reached 6 m in height--all houses were swept away except two that were standing on high lava ridges.

The earthquake itself was the largest historical one in Hawaii (Furumoto et al. 1973). The intensity of the shock over the southern part of Hawaii was 10°, on the northern part 9°, on southern Maui 8°, on northern Maui and Lanai 7°, on Molokai 6°, on Oahu 5°, and on Kauai 3° and 2°, respectively. It was preceded by 6 days of foreshock activity, and hundreds of aftershocks followed the principal one of April 2.

As mentioned, the tsunami might have been caused by the mudflow, the slip of which resulted from the main quake. "A study of the records of the time indicated that both the volcanoes Kilauea and Mauna Loa were unprecedently active before the culminating shocks, and that Kilauea had been unusually active for several months before the quake. During and after the main shock, Kilauea overflowed lava and large portions of the crater walls tumbled down. A large portion of the floor caved in to a depth of about 500 feet (152 m) covering an area 8,000 feet (915 - 1829 m) long and from 3,000 to 6,000 feet wide. However, this earthquake was tectonic and not volcanic, although there was volcanic action" (Furumoto et al. 1973, p. 22). Thus the tsunami was indirectly correlated with the eruption of Kilauea Iki. The collapsed volume in the caldera of Kilauea is estimated as 188,300,000 m^3, having a surface area of 3,060,000 m^2 (MacDonald 1955).

171. 1868 November 8 - 9--Unnamed submarine volcano near St. Helena Island, southern Atlantic

In the night the sea was disturbed and detonations were heard at 16°40'S, 4°W--some 190 km off St. Helena Island. The ship "Ephrosine" trembled and the compass was continuously disturbed. Fishes were thrown in the air. At the site of the phenomenon the depth of the water is 5,300 m; therefore, a submarine eruption affecting the surface is questionable. According to Neumann van Padang et al. (1967), the event might have been the consequence of a seaquake. No tsunami was reported, however.

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172. 1869 May 6--Submarine eruptive center near Smith Rock, Izu-Mariana Islands

An eruption has been reported at 31°00'N, 139°02'E, but no details are known (Kuno 1962).

173. 1870 May 11--Nameless submarine volcano near Smith Rock, Izu-Mariana Islands

Another submarine eruptive center has been active

at 31°35'N, 140°30'E, but no details are available (Kuno 1962).

174. 1870 July 6--Raoul Island, Kermadec Volcanic Group

An eruption under the sea was reported. A parasitic crater has probably been active at 29°14'S, 177°55'W (Richard 1962).

175. 1870 October 15--Santorini, Aegean Sea

The last explosions happened inside the caldera, after which only fumarolic activity has been observed and finally insignificant emanations of water vapors, CO_2 and sulfur gases at the top of Georgios (Georgalas 1962) marked the end of the long eruption-cycle that began on 1866 January 26. See item 156.

176. 1870--Submarine eruptive center southeast of O-sima, Izu-Mariana Islands

Eruption of pumice at a point about 320 km southeast of O-sima is mentioned by Sapper. The exact location is not given, but as this point lies to the east of the Japanese Trench, an eruption here is very unlikely. It can be supposed that it might have been a floating "raft" of pumice that originated far from this location at an unknown source (Kuno 1962).

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177. 1870--Submarine volcano near Smith Rock, Izu-Mariana Islands

An eruption occurred at a point 18 km southwest of the Smith Rock. The exact coordinates of the event are not available. An island 13 m high was formed and it was seen in 1923 (Kuno 1962).

178. 1871 March 2 - 14--Ruang, Sangihe Islands

A strong explosive eruption from the central crater, devastation of arable lands, and casualties were reported. Three great tsunami-waves came from the sea, owing to the mighty landslide from the top of the mount; the soil and the rocks had rolled into the water. The first wave reached the height of 25 m! It penetrated 180 or 200 m inland on Palau Tahalandang at the town of Buhias. Three villages were completely destroyed and 460 persons lost their lives (Heck 1947, Berninghausen 1969). The tsunami magnitude was assigned as about 4 (Iida et al. 1972). This great tsunami took place on March 5 and accompanied one of the outbursts of Ruang.

179. 1871 March 29--Near Bayonnaise Rock, Izu-Mariana Islands

The eruption of a nameless submarine volcanic center is mentioned by Sapper (1927) but he gives no details. The event is doubtful. No data were found in other sources. No coordinates are given; the event is located south-southwest of the Bayonnaise Rock.

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180. 1871 April--Near Tori-sima, Izu-Mariana Islands

Submarine outbreak, no details. Location of Tori-sima: 30°28'N, 140°14'E (Kuno 1962).

181. 1871--Submarine volcano near Smith Rock, Izu-Mariana Islands

An outbreak from the water has been reported at 31°30'N, 139°30'E (Kuno 1962). No further details are known.

182. 1871--Maurelle Islands, Tonga Volcanic Group

Sapper (1927) has mentioned that in this year new islands came into being very near Metis Shoal (see items 128 and 147, respectively), but they disappeared later. For Metis Shoal itself he gave the following coordinates: 19°11'S, 174°51'W.

183. 1872 August 10 - 1877 February--Mauna Loa, Hawaii

Continuous activity was observed from the summit caldera. On 1872 August 23 (or August 27?) a small tsunami was observed with a maximum height of 1.3 m and with a magnitude of 0 (Pararas-Carayannis and Calebaugh 1977), and the corresponding energy is some 1.51×10^{21} ergs. Jagger suggested that the tsunami was caused by a local volcanic event and Sapper associated it with the eruption of Mauna Loa. Altogether 14 diminishing oscillations were experienced and they lasted for 1.5 hours. According to Pararas-Carayannis and Calebaugh (1977) as well as Iida et al. (1972) this was a distant tsunami or perhaps a storm surge but not a true tsunami of volcanic origin, in contrast to Jaggar's and Sapper's opinions.

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184. 1872--Raoul Island, Kermadec Volcanic Group

Submarine outburst that led to the formation of a new island that remained above the sea until 1877 has been noted. Location: 29°12'S, 178°00'W, in the Denham Bay (Richard 1962).

185. 1873 (?)--Submarine volcano near Smith Rock, Izu-Mariana Islands

Uncertain outbreak at 31°17'N, 139°55'E (Kuno

1962). Details are not available.

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186. 1874 April 30--Unnamed volcano between Hapai and Tonga, Tonga Volcanic Group

No exact location is given by Sapper (1927) and no details are mentioned by Richard (1962). Uncertain.

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187. 1875 March 28 - May - June--Slamet volcano and its vicinity, Java

On March 28 a tsunami was observed at 8°16'S, 110°40'E. At the end of May, the same year, an eruption of Slamet volcano began and lasted until the first days of June. Note that the coordinates of the volcano are 7°14'S, 109°12'E; that is, it lies rather near the point where, according to Visser (1922), the seismic sea wave was experienced two months prior to the commencement of the outburst. It can be supposed, therefore, that the tectonic shock that caused the tsunami triggered the volcano to erupt. If so, the tsunami and the eruption were indirectly associated with each other. It is interesting to note, furthermore, that on 1875 March 28, a 4-m high tsunami with a magnitude of about 2 was observed in the Loyalty Islands, New Hebrides, and New Caledonia (Iida et al. 1972), but the coincidence of the occurrence of the shock that caused this tsunami with the commencement of Slamet's eruption is evidently only due to chance.

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188. 1876 April 16 - 1878--Metis Shoal, Tonga Volcanic Group

Continuous activity, origin of a new island with a maximum diameter of 160 m and maximum height of 35 m (Neumann van Padang 1938).

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189. 1876 December 10--Nameless submarine volcano near Tiera del Fuego, Scotia Arc, Antarctica

An underwater eruption at 65°15'S, 72°10'W was mentioned by Berninghausen and Neumann van Padang (1960). Allegedly an ephemeral island of conical shape came into being, but this is uncertain. Sapper (1927) mentioned an island with a height of 30 m, but this disappeared on the same day. The coordinates are given by Sapper as follows: 65° 15' S, 75° 12' W. MacDonald (1972) gave 56° 15' S, 72° 10' W. Simkin et al. in "Volcanoes of the World" (Smithsonian Institution, 1981) give 56.25° S, 72.17° W.

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190. 1877 February 2 (or February 24?)--Mauna Loa, Hawaii

A tsunami was observed along the Kona Coast (southwestern part) of the Big Island of the Hawaiian archipelago. Mauna Loa began to erupt along its western slope on 1877 February 14--that is, if 1877 February 2 is accepted--long after the occurrence of the tsunami. At the same time a submarine eruption 55 m below sea level happened off Kealakekua Bay, on the west coast of Hawaii (MacDonald 1955). However, as it is explained by MacDonald, it is unlikely that such an underwater eruption would create a tsunami affecting the Kona Coast, and according to Iida et al. (1972) submarine eruptions along this coast are also very unlikely. Hence we can suppose that the tsunami originated from an unknown source far west of Hawaii and was not associated with the eruptions mentioned. Concerning the seismic sea wave itself, no further details can be found in the literature.

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191. 1877 May 4--Kilauea, Hawaii

A tsunami of magnitude 1 was experienced at Hawaii (Pararas-Carayannis and Calebaugh 1977), but no details are available. Eruption from the caldera wall of Kilauea occurred on the same day (MacDonald 1944). Note: In the east rift zone--more exactly, in the Keanakakoi crater--another eruption took place on or about 1877 May 21. The tsunami of 1844 May 4 is not mentioned by Iida et al. (1972).

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192. 1877 June 15--Pisagua, near the coast of Peru

Mighty columns of smoke emerged from the ocean at Pisagua (Sapper 1927). No data on the exact location are known. Uncertain.

⊼ ?

193. 1877 December 1--Submarine eruption in the New Zealand volcanic zone

According to Sapper (1927) an eruption took place at 38°S, 178°E. The event is uncertain, as no data about it can be found elsewhere.

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194. 1877--Falcon Island, Tonga Volcanic Group

Smoke was seen issuing from the ocean (Richard 1962).

⊼ ↑

195. 1877--Raoul Island, Kermedec Volcanic Group

The small islet in the Denham Bay that originated in 1872 disappeared (see item 184), but the so-called Wolferine Rock remained above the level of the water (Richard 1962).

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196. 1878 January 10--Tanna, New Hebrides Islands

According to Heck (1947) at Port Resolution the sea rose 12 m, and this was accompanied by a maximum rise of 3.3 m of the ocean bottom. Sapper (1927) is of the opinion that the height of the tsunami reached 17 m. Volcano Tanna (other names are Yasour or Yasowa, etc.) erupted on this day. A new crater opened on the volcano; the tsunami might have been caused by an earthquake (Iida et al. 1972). The tsunami magnitude is estimated to be about 3, the

corresponding energy of which is 1.58×10^{23} ergs. A second earthquake and eruption, with a smaller tsunami, occurred a month later.

197. 1878 January 29--Nameless submarine volcano, equatorial Atlantic

The sea was in great commotion, and large columns of water were thrown about 30 m into the air. There was a sound like distant thunder. The probability of an underwater outbreak is, however, questionable. The location of the event is 4°12'N, 21°27'W (Neumann van Padang et al. 1967).

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198. 1878 February 4--Raluan, New Britain

Heck (1947) has mentioned two seismic sea waves in association with an eruption of Raluan (other names are Ghaie or Vulcan), which belongs to the Rabaul Volcanic Group. According to Iida et al. (1972, pages of items "1878. Jan. 10. ... 1878. Feb. 4."), two "flood waves" were observed--probably two waves of a tsunami and not tsunamis as interpreted by Heck. Heck gave February 4 as the date but Sapper said only that "the waves occurred during an eruption which lasted 4 days starting Feb. 4." According to Fisher (1957) a very severe, explosive eruption took place from Raluan. A great mass of ash and pumice was thrown out. Vulcan Island was built up. Old charts show an island existed here long before the event, so other outbreaks had taken place from this center earlier. We have no data, however, about this earlier activity. Note: The first known outburst of the nearby Matupi began a day or so later than the eruption at Raluan. The two volcanological events were, without any doubt, physically correlated with one another. Tsunami magnitude was about 1.

199. 1878 August 11--Tanna, New Hebrides Islands

Eruption of the volcano, an earthquake and a tsunami with a magnitude of about 1 (corresponding to an energy of 1×10^{22} ergs) were reported (Iida et al. 1972).

200. 1878 February 29--Tuliskoi, Aleutian Islands

A tsunami was observed near Unalaska Island. The town of Makushin was destroyed by both the earthquake and the seismic sea wave, and the magnitude of the latter was estimated to be about 1 (Iida et al. 1972). Note: It is not certain, but can be supposed, that the earthquake that caused the tsunami might have had a triggering effect on a nearby volcano--in all likelihood Tuliskoi--which exhibited a very strong ash eruption and on which a new crater developed in 1878 (the date given in the heading of this item refers to the date of the tsunami; for the volcanic eruption only the year is given by Sapper [1927]). We considered Tuliskoi because this volcano is to be found just in front of the Makuhsin Bay where the tsunami has been observed. The only other volcano that was active in 1878 in this region is Vsevidof. But Vsevidof is much further from the Makushin Bay than Tuliskoi and therefore its effect is unlikely. In our opinion the tsunami was indirectly related to the eruption of Tuliskoi; both were triggered by the earthquake mentioned.

201. 1878--Metis Shoal, Tonga volcanic group

Submarine activity was noted. The new island, which was born in 1858 (see item 188), was about 180 m long and 33 m high. It ejected great quantities of white smoke (Richard 1962).

202. 1879 May 30--Eldey, Iceland

A submarine outburst was reported to have occurred on the same spot as in 1830 (see item 103). A small ash fall was also described (Berninghausen 1964).

203. 1879 December 31-1880 March (end of the month)--Lake Ilopango, Islas Quemadas, El Salvador

At first we give the summary of the event in terms of the Catalogue of Active Volcanoes of the World (Mooser et al. 1958), and then we shall quote the original text of a paper in Nature more than a century ago (Nature, 22, 10 June, 129, 1880).

a) Severe earthquakes were the prelude of the eruption. The first shocks took place either on December 20 or 21, 1879. Lava extrusions began on December 31 in Lake Ilopango, an 11-km long and 8-km wide volcano-tectonic depression. The eruption caused a rise of the water level by 1.22 m. On January 20 the lava reached the surface of the lake. Explosions occurred. At the end of January the island had a diameter of 150 m, and a height of 30-40 m; at the end of February its top reached about 50 m above the water level.

b) A Lacustrine Volcano. In a recent number of La Nature further details, furnished by the French Consul of San Salvador, M.J. Laferriere, are given concerning the recent volcanic phenomenon in Lake Ilopango in that State. The accompanying illustration, from a photograph, will show the nature of the crater which has risen in the midst of the lake. Earthquakes were felt in San Salvador in the first half of January of this year (1880--note by author), there were three strong shocks, less violent, however, than those of 1876. These earthquakes had their center in the vicinity of Lake Ilopango, in the midst of which rose three volcanic openings connected with each other. This new crater, which, seen from a distance as in the illustration, appears a small islet, rises above the surface of the water, however, about twenty meters. An attempt was made to approach it in a boat, but the waters were all in a state of ebullition from contact with the burning rock, and gave off torrents of steam. An abundant column of smoke rose in the air, assuming the aspect of an immense cloud, which was seen from a great distance, and formed an imposing spectacle. The phenomenon was preceded by an exceptional rising of the lake, increased by the abundant

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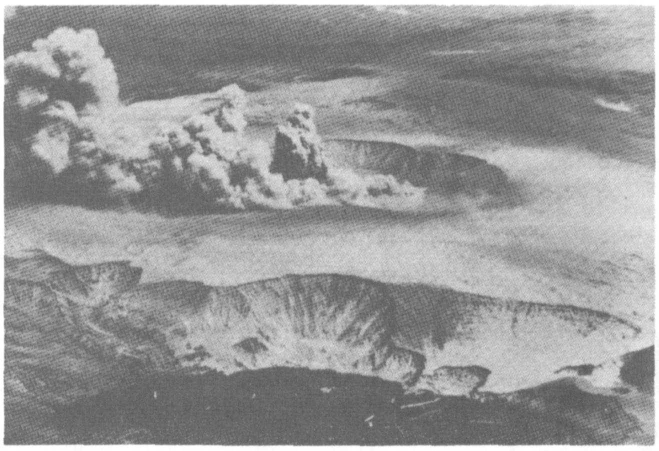

Figure 203/1.-- Aspect of the volcano in Lake Ilopango (after Nature).

winter rains. According to an old tradition the Spaniards maintain that when the lake rises earthquakes are to be feared. Formerly, also, it was the custom to dig trenches to facilitate the escape of the waters. This practice was followed without intermission for a century, and volcanic phenomena did not appear during all that time. The present phenomena seems to justify this tradition. It is difficult to explain the fact it is still interesting to remember that a great number of volcanos are submarine, that others are found for the most part in islands or in maritime regions, and that water may be one of the feeders of volcanic fires. Lake Ilopango, also known as Lake Conjutepec, is, according to M. Laferriere, a sunk crater. It is in the volcanic line, and it is a general fact in Central America that lakes alternate with volcanic cones. The water of this lake is brackish, very bitter, and almost viscous. It gives off sometimes, here and there, bubbles of sulphohydric acid gas. The lake is about 12 kilometers long and by 16 broad (? - question mark from author); the depth is unknown. It is about 12 12 kilometers from the city of San Salvador. The Consul of France in Guatemala, M. de Thiersant, states that Lake Ilopango has now a temperature of 38°C on its shore, and is in complete ebullition around the volcano. All the fishes are cooked and float upon the surface, with a great number of shellfish and other aquatic animals. The volcano continues to rise, and the level of the lake is being gradually lowered.

After the manuscript for this catalogue had been completed an interesting paper was published by P. D. Sheets, entitled "Volcanoes and the Maya" (Natural History, August 1981, pp. 32-40), in which the author discussed a particularly violent, earlier outurst from Lake Ilopango. The event took place about A.D. 260, near the northwestern shore of the lake. A new crater opened beneath the level of water from which a mighty mass of tephra was thrown out in two successive steps during a very short time, perhaps only a few days or even hours. In the Chalchuapa Valley, 72 km northwest of Lake Ilopango, the thickness of the ash reached 1 m. The total volume of tephra might have been greater than 41 km^3, which means that this eruption was one of the greatest during human history. The layer of ash at the shore of the lake had a thickness of 48-50 m. In all likelihood the eruption took place between May and November. This exceptionally powerful eruption caused the wandering of the Mayas toward the north, to a place that is now known as Maya Plain.

Taking into account the expression

$$M_e = \frac{\log V + 4.95}{1.5936957}, \qquad \text{(Hedervari 1963)}$$

where M_e is the eruption magnitude and V the volume of tephra, we get 9.763 for the eruption magnitude, from which the released thermal energy is 4.18 X 10^{26} ergs.

NOTE: sulphohydric acid gas is probably hydrogen sulfide, H_2S.

204. 1879. Georgiana, Ninety East Ridge, Indian Ocean

Floating pumice has been seen at 6°S, 89°E (Sapper 1927, Neumann van Padang 1938, 1963). Note: The spot in question lies very far from the mid-oceanic rift valley of the Indian Ocean and far from any other well-known volcanic area. Geographically and geophys-ically it belongs to the Indo-Australian Seismic Belt, which--probably--is a nascent mid-oceanic rift valley and ridge zone, characterized by rather vivid seismicity, high heat flux, and richness in seamounts but a very mild present-day volcanic activity (Hedervari 1978a). Floating pumice at and near this point was seen in other times as well. The known cases, when floating pumices were seen, are as follows:

In fig. 204/1	In fig. 204/2	Date	Location
1	a	1879	6° S, 89° E
1	a	1883 July 11-12	6° S, 89° E
1	a	1883 August 1	6° S, 89° E
2	b	1883 August 11	6°23'S, 88°31'E
3	c	1883 August 17	8°35'S, 91°53'E
4	d	1883 August 18	9°41'S, 90°28'E
5	e	1883 August 19	11°08'S, 88°03'E

According to Neumann van Padang (1938, 1963), on 1883 July 11 and 12, H.O. Forbes sailed through floating pumice; on 1883 August 1 Captain E. Ashdown sailed his ship "Siam" for 4 hours through fields of floating pumice, which means a distance of about 60-80 km at the most. He had the opinion that a submarine eruption must have occurred there. He said, further-more, that another outbreak had taken place at this point in 1879. All of the other reports, from 1883 August 11 to 18 are from C. Moldrum. He had the opi-nion that the pumices he saw originated from Krakatau volcanoe (Sunda Strait), active since 1883 May 20.

The author feels it reasonable and important to quote here some sentences from the original text of the work of Neumann van Padang (1938, item No. 76):

"76.6° S - 89° O. Am 1. August 1883 fuhr das Schiff 'Siam' mit einer Geschwindigkeit von 11 Knoten wahrend vier Studen durch Bimmssteinfelder (im Text steht Lava), die sich, so weit das Auge reichte, ausstreckten. Der Bimsstein trieb in NW-SO gerichteten Streifen. Da eine Stromung von 75--30 Meilen pro Tag in

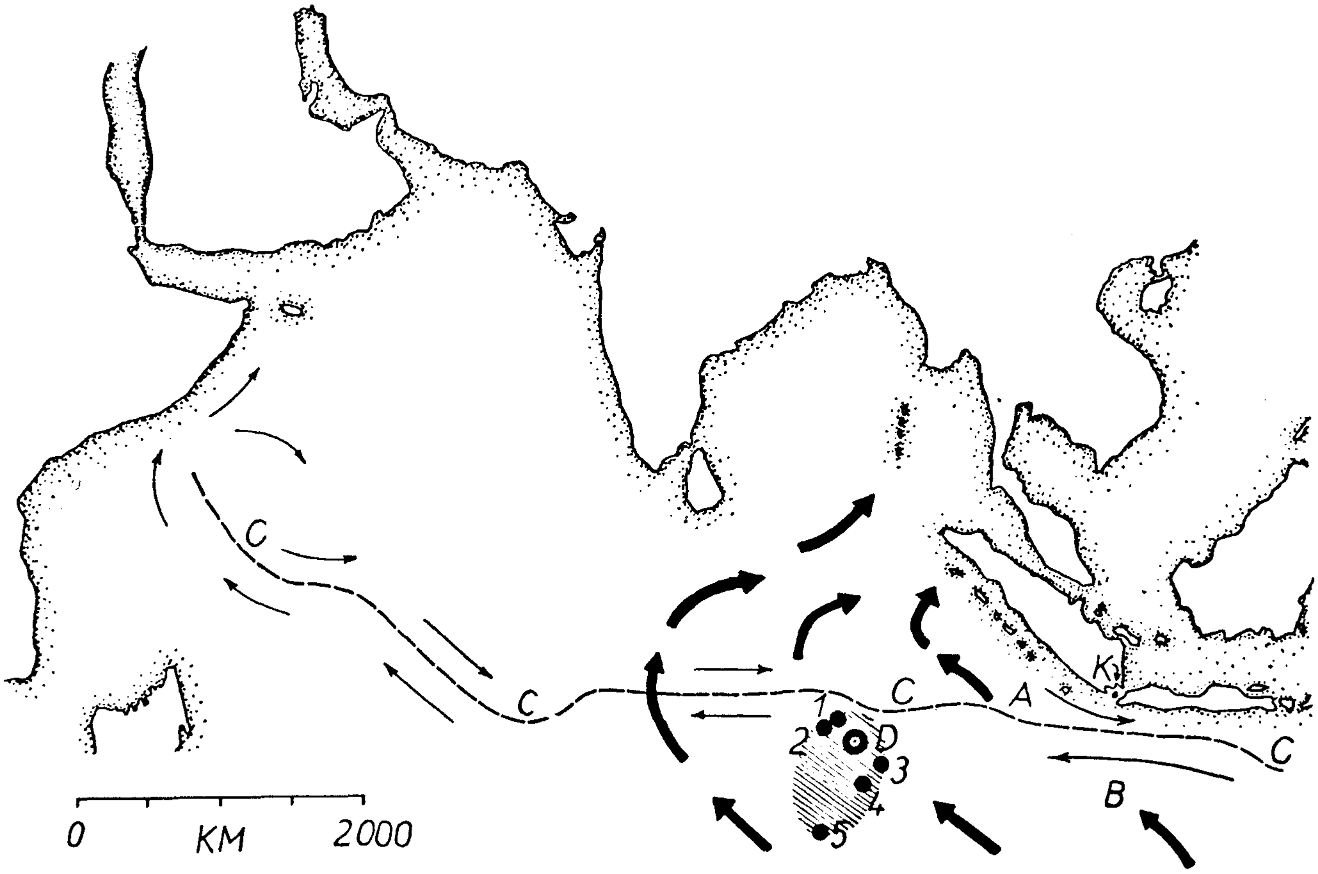

Figure 204/1. The site of the occurrence of pumices floating on the water (1 - 5) and its environs. K: Krakatau volcano; A and B: oceanic currents; C: dividing line; D: the spot with the abnormally high value of heat flow (7.61 HFU); thin arrows: oceanic currents; thick arrows: winds during the summer in the Northern Hemisphere. Currents and winds after Fairbridge (1966, 1967). Line C is also after Fairbridge (1966)

ostlicher Richting herrschte, so meinte Kapitan Ashdown, das dieser Bimsstein nicht vom Krakatau, sondern von einem ortlichen Austruchspunkt im mehr als 3600 m tiefen Ozean stammt. Er meldete von diesem Platz auch einen Ausbruch im Jahre 1897. Die beobachteten Bimssteinstreifen waren etwa 1800 km vom Krakatau entfernt, der erdst am 26--28. August grosse Mengen Bimsstein gefordery hat, so dass die Annahme, dass ein starker Vulkanausbruch in gosser Tiefe stattgefunden hat, gerechfertig ist."

As mentioned above, Moldrum has suggested that the pumice masses came from Krakatau. The present author argues against this supposition. The arguments are as follows:

a. The initial activity of Krakatau was relatively mild and the explosions were not particularly violent (Williams 1941, Bullard 1968, MacDonald 1972). The activity began after a 202-year long repose on 1883 May 20. This initial activity continued with decreasing intensity for a little more than a week, and Krakatau then was in a calm state until 1883 June 19. Weak to moderate eruptions followed after this day (MacDonald 1972), at least intermittently, through July and the paroxysmal eruption began as late as 1883 August 26.

The products of the first 4 days of the activity formed a layer with a maximum thickness of 1 meter (Williams 1941). When the volcanic islands were visited for the last time before the paroxysmal stage on 1883 August 11, it was stated that only a little fragmental material had been addfed to the thin layer left by the activity of the first 4 days. Ninety-eight percent of the total ejecta was thrown out during the paroxysm from August 26 to 28. The total quantity of ejecta was estimated by Verbeek to be at least 18 cubic km. Two-thirds of this material fell within a radius of 15 km. As stated by Williams, only the finer particles of pumice were shot high into the air, and these were carried away by the winds for thousands of kilometers.

Considering the facts that (1) prior to the paroxysm the activity had been weak to moderate only, and (2) that the quantity of the ejecta of this period was about two percent of the total, it is unlikely that betwen 1883 July 11 and 1883 August 19 a large quantity of pumice would have been scattered over an area of 600 x 900 km in extent, at a distance of some 1700-2300 km from the volcano. Note that the area within which pumices were found is elliptical with a major axis of some 900 km and a minor axis of approximately 600 kilometers, and the distances between Krakatau and the eastern and western edges of this elliptical area are 1700 and 2300 km, respectively.

b. As previously mentioned pumice was seen as early as in 1879 at 6°S, 89°E. These pumice-masses have evidently nothing to do with the activity of Krakatau in 1883. Therefore another source of the pumices must be supposed.

c. From the map of currents in the Indian Ocean (Fairbridge 1966, p. 384, Fig. 21), it is perfectly obvious that pumice ejected from Krakatau toward the south or southeast, somewhat beyond the mouth of the Sundra Strait, was carried further by the oceanic currents toward the east, parallel with the southern coast of Java. Floating objects in front of the Sunda Strait can not be transported toward the west, since along the southern entrance of the Sunda Strait the current flows from the northwest towards the southeast and east (see arrow A in Fig. 204.1. Between this current and another having the opposite direction (see arrow B), there is a dividing line (see dashed line C), which distinctly separates currents A and B from one another. Current cannot cross this line. In short: pumice from Krakatau can never reach the elliptical area lying far west from the volcano.

It is very remarkable, furthermore, that there are no reports of the presence of pumice along the southern coast of Java and the Lesser Sunda Islands, or along the northwestern coast of Australia in the period that preceded the paroxysm of Krakatau. In the case of creation of great pumice masses during the pre-paroxysmal stage, these pumices should have been observed first of all over the Java-Lesser Sundas-Australia area, because this region lies in the way of the oceanic currents. In the lack of reports on the occurrence of floating pumices over this critical area, that is east and southeast of the mouth of the Sunda Strait, the question arises: was the mass of pumice originated during the pre-paroxysmal period remarkable at all? If so, why was this pumice unobserved so near the source? If not, how could a remarkable mass of pumice (as mentioned, one of the floating masses might have had a diameter of some 60-80 km) reach a site very far from the source, and moreover west of it -- a direction just opposite to the direction of the oceanic currents?

On the basis of these statements it can be declared with great certainty that the source of the pumice observed in the elliptical area was not Krakatau volcano.

d. Considering now the wind system over the eastern part of the Indian Ocrean south of the Bengal Bay, during Northern Hemisphere summer (Fairbridge 1967, p. 1148, Fig. 2), the conclusion is the same. It can be seen that during the period of 1883 July 11 - August 19, the direction of the wind was clearly unfavorable to carry very fine pumice from Krakatau into the elliptical area within which the floating pumice was seen. In addition, and this is similarly evident, the explosive force active during the pre-paroxysmal period was not able to throw pumice to such a great distance.

e. The paroxysmal eruption led to a great ash-and pumice-fall, and an area of 827,000 square km was covered by these products (van Padang 1951). If the area is considered to be more or less circular, which is only an approximation, the radius of the circle is 513 km. But the center of the elliptical area is about 2000 km from Krakatau. During the relatively weak initial period of activity (1883 July 11 - August 19) the pumice could not have reached such a great distance, which is roughly four times greater than the "theoretical" value (513 kilometers) that refers to paroxysmal eruption.

It should be noted that the real area of volcanic ash had a triangle form; see Bullard (1968), Fig. 8. on p. 82. It must be emphasized, however, that Bullard's map shows the areal distribution of ash and not that of pumice. As regards the latter, erupted pumice, flying through the air, never can reach the great distance from the volcano than ash can. "If a strong wind is blowing at the time of the eruption, only the lumps of pumice will fall in the vicinity of the volcano, while the ash will be carried much further..." (Rittmann 1960, p. 75.)

Taking into consideration the wind directions at the time of the paroxysm, and considering this strongly asymmetrical distribution of ash relative to the site of Krakatau, one can suppose that this peculiar distribution might have been the consequence of directed blast or blasts.

Based on the previous five aguments and particularly on point c., the author concludes that the pumice masses that occurred in the elliptical area at the central part of Ninety East Ridge cannot be the products of Krakatau volcano but originated in situ. That is, there must be a submarine volcano at this locality.

It is often said that pumice can only form in shallow water. We are aware of at least 2 examples, that contradict this statement. The author has asked the opinion on this problem of Dr. M. Neumann van Padang who kindly gave him the following information (Neumann van Padang, written communications, 1981 July 4 and 1981 August 6, respectively):

> "Pumice originates when a glassy magma rich in silicic acid erupts. A. Brun described in his publication 'Recherches sur l'exhalaison volcanique, 1911' that pumice may originate in the laboratory when obsidian is heated to its explosive point. That is why the origin of pumice is not dependent on its place or on a submarine eruption (italics mine: Hedervari)

> "In May 1761 an 'island of volcanic sand' was seen in the Atlantic Ocean at 0°23'S and 19°10'W. As this island never has been seen since, it probably was floating pumice (Catalogue of Active Volcanoes of the World, Part 21, p. 121). On the map of the National Geographic Society of 1955, I found a submarine mountain rising from a depth of about 3660 m to 1528 m in 0°43'S and 20°30'W. Eruptions of this mountain are also known from December 1816 and January 1836. If the supposition that 'the island of volcanic sand' indeed was floating pumice, eruptions at a depth of 1500 m may indeed form pumice" (italics mine: Hederavari) And: 'In my opinion pumice is formed when the erupting magma [is] rich in silica and still vitreous independent of the place of the crater, which may be 1000 m above or below sea level." (italics mine: Hedervari)

There is another example. A submarine volcano is known at 38°45'N, 38°05'W (Neumann van Padang et al. 1967). On the map of the National Geographic Magazine 1955, the ocean is about 4,200 m deep at this point. A topographic high of less than 2,000 m is located about 74 km to the east. In 1865 July 9, a submarine eruption took place at 38°45'N, 38°05'W, or close to

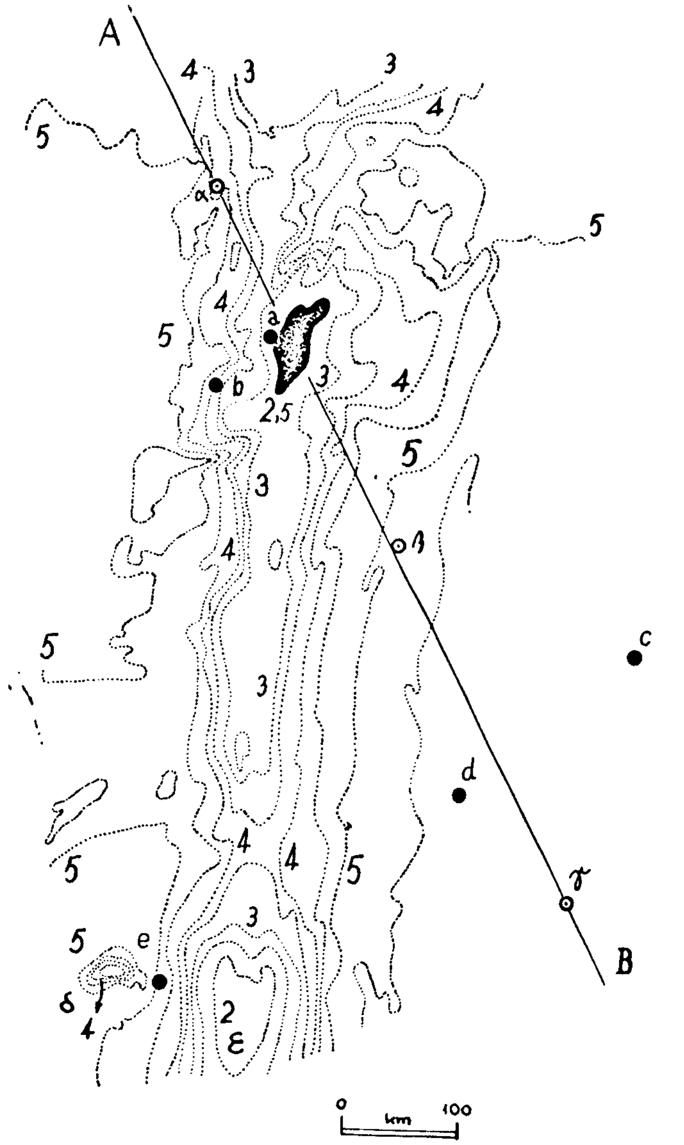

Figure 204/2. Topographic contour map of the central part of Ninety East Ridge (after Sclater and Fisher (1974). Depths are given in kilometers. Points a - e are sites of floating pumices (corresponding to 1 - 5 in fig. 204/1). Alpha, beta, and gamma are points on which heat flow measurements have been carried out. Beta corresponds to point D in figure 204/1. AB: section.

it, as scoriae, probably pumice, reached the surface of the sea, where it formed a "floating mountain." A strong smell of sulphur was perceptible and dull rumblings were heard by the crew of the whaler "Firmesa."

These two submarine eruptions are numbered 62 and 154 in the present Catalog.

Sclater and Fisher (1974) have published an excellent contour map of the Ninety East Ridge on which the surroundings of our elliptical area can be investigated in more detail.

A part of this map, namely, the central region of the Ninety East Ridge, where our elliptical area can

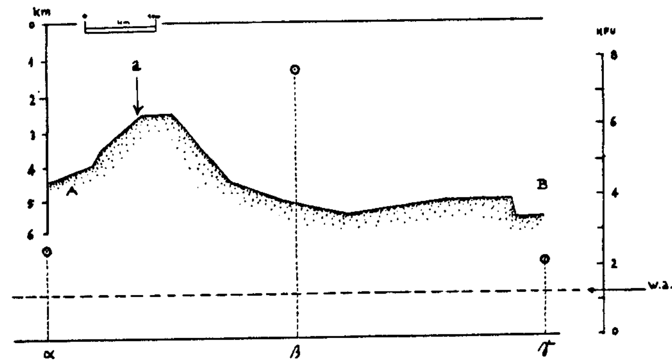

Figure 204/3. Profile along section AB, with great vertical exaggeration. Alpha, beta, and gamma are heat flow values; w.a. = world average of heat flow.

also be found, is shown in Fig. 204/2. The numerals mean the depth of the water expressed in kilometers. One can see that a plateau-like elevation is to be found on the northern portion of the demonstrated part of the Ridge (shown by black contours). It has an average depth of 2.5 km below sea level and has an elongated form with a length of some 90-100 km, but its width is about 25-30 km. The profile of this feature, shown in Fig. 204/3, is rather misleading because of the strong vertical exaggeration of the drawing in question; in reality the feature is much flatter, similar in form to a shield volcano or a seamount. It is noteworthy that one of the sites on which pumice was seen on three occasions, denoted by 1 in Fig. 204/1. and by a in Fig. 204/2, is to be found just at the western edge of the feature. Point 2 = b, another site of pumice, is situated west of the southern tip of this feature at a distance of some 60 km. The author is of the opinion that this submarine elevation can be regarded as the inferred underwater volcano. South of this area there are two other submarine elevations denoted by greek delta and epsilon in Fig. 204/2, which can also be regarded to be volcanoes. Point 5 = e lies between them. The writer prefers, however, the northern elevation instead of those designated delta or epsilon, because in its near proximity pumice were observed altogether four times (as mentioned, a means three cases and b an additional case), but e represents only one observation.

Fortunately, we have three data concerning the heat flow in the surroundings of the inferred submarine volcano, and - incidentally - the measurements have been made along a line, so to construct a profile showing the distribution of heat flow was possible easily. The trend of this line is denoted by A and B, while the three points over which heat flow measurements have been carried out are denoted by the greek letters alpha, beta, and gamma, respectively. The measurements were made by the Lamont-Doherty Geological Observatory. The data were published in computerized form by the Massachusetts Institute of Technology. The date of issue of this list is not indicated in the publication in question.

From this list one finds the following values:

alpha:	4°46' S, 88°34' E:	2.55 HFU
beta:	7°42' S, 90°02' E:	7.61 HFU
gamma:	10°37' S, 91°19' E:	1.12 HFU

in heat flow units (HFU)

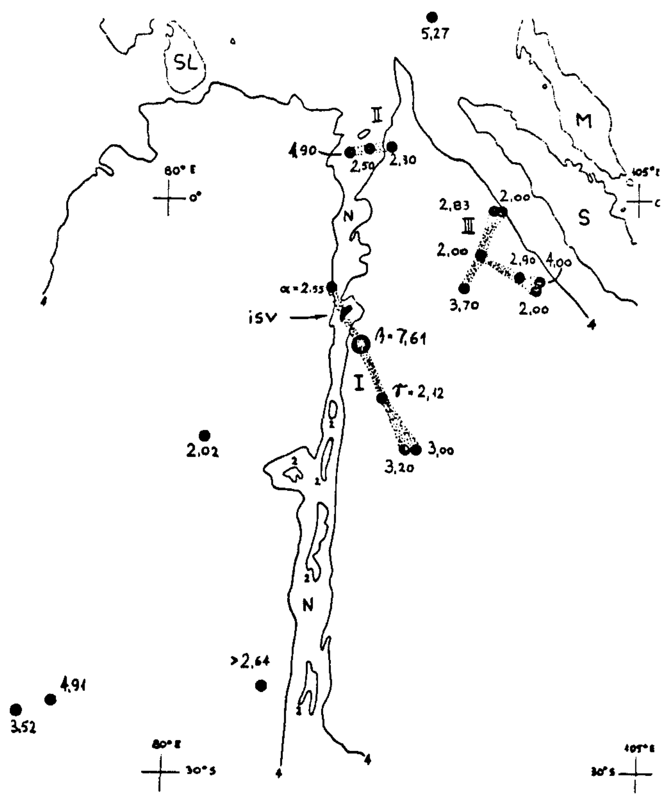

Figure 204/4. Points with measured heat flow values ⩾ 2.0 HFU. SL: Sri Lanka (Ceylon); M: Malaysia; S: Sumatra; N: Ninety East Ridge. Depth values given in kilometers. Belts I, II, and III (dotted) are linear zones of heat flow anomalies. Isv = inferred submarine volcano. Note that it can be found within belt I, the length of which is some 1100 km.

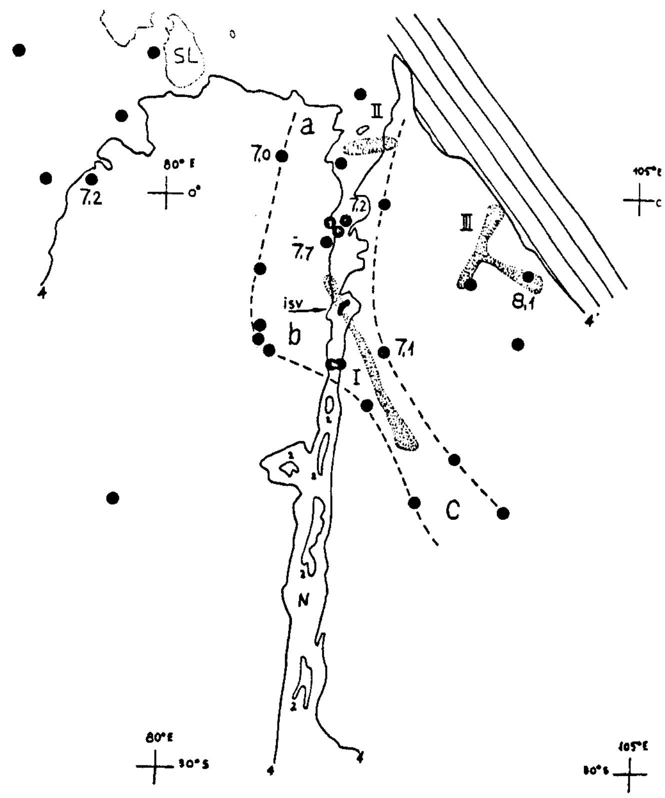

Figure 204/5. Distribution of the epicenters of powerful tectonic shocks between January 1, 1904, and December 31, 1965. All known earthquakes are indicated; all were of shallow origin. Black circles: Richter magnitude less than 7.0. Black circles labeled with magnitudes denote earthquakes of Richter magnitude 7.0 or greater. Thermal anomaly belts I, II, and III are dotted. Isv = inferred submarine volcano. Note the correlation between seismicity and heat flow anomaly belts. The zone of great earthquakes extends from a through c. Belt I lies along the seismic zone axis between b and c. The northern part of Ninety East Ridge is active seismically; the southern part is practically aseismic. Earthquakes that occurred in the Andaman-Indonesia zone (striped) are not indicated. SL: Sri Lanka; N: Ninety East Ridge.

Using all available data for heat flow (Lee and Clark 1966, Simmons and Horai 1968, as well as Lamont-Doherty list, mentioned above) the author has constructed the map of distribution of large heat flow anomalies in the Indian Ocean, in and around the Ninety East Ridge (Fig. 204/4). On this map only those points are indicated over which the heat flow reached or surpassed the value of 2.00 HFU, which is well above the world average. It can be stated that within the area investigated (73° E - 105° E, 10° N -Equator - 31°30' S), by far the greatest value is that one which was observed at point beta. In addition, as shown in Fig. 204/4, there are altogether three belts of heat flow anomalies in this part of the Indian Ocean; these are denoted as I, II, and III, respectively. Among them belt I is the longest; this contains the points alpha, beta, gamma, and two other points characterized again with high values, roughly double the world average. They are to be found at the southern end of belt I. This belt of high heat flow anomaly crosses the place of the inferred submarine volcano (ISV). Comparing this belt of heat flow anomaly with the zones of active volcanoes in island arcs, it can be stated that more or less similar, linearly developed belts of high heat flow characterize the volcanic chains, too. Such belts may be the consequence of the existence of linearly aligned (shallow) magma chambers that are to be found relatively near the surface, at a depth of only a few kilometers. The presence of such a submarine anomaly-belt with a length of some 1100 km, exactly crossing the critical isv-region, appears to strongly support the hypothesis that the isv-region is really the site of a submarine volcano.

The tectonic importance of these three heat flow anomaly belts is emphasized by the seismic pattern. In Fig. 204/5 the author has indicated the distribution off epicenters of large earthquakes that took place from 1904 January 1 to 1965 December 31, using the data published by Gutenberg and Richter (1954), Rothe (1969) and Duda (1965), respectively. All shocks with a Richter-magnitude of $M \geq d$ (where d means a value ranging from 5.3 to 5.9) are indicated by black circles. In the case of $M \geq 7.0$ the corresponding magnitude values are also shown. All these shocks were of shallow ($h<70$ km) origin.

The most powerful earthquake, having a Richter-magnitude of 8.1 (Duda 1965) took place within belt III. As regards belt II, it can be found in the northern part of a broader seismic zone (denoted as a-b-c) with a strong (M = 6.3) shock a little southward from its western edge. The most interesting is, however, belt I, which is to be found along the symmetry-axis of the southern part of this broad seismic zone. This southern part is denoted as b-c in Fig. 204.5. Near the center of belt I is a powerful earthquake with a magnitude of 7.1 took place. Inspecting the general pattern of seismicity we can state that the northern half of Ninety East Ridge is seismically very active, while the southern half of it is practically isv-region, the site of the suspected submarine volcano, occurs within the active segment of Ninety East Ridge, especially just on that point where the strike of the a-b-c seismic belt changes abruptly. Consequently:

a. The existence of a broad and long seismic belt demonstrates the presence of a zone of weakness in the oceanic lithosphere;

b. the zone of weakness means a strip within which deep fractures can originate; the shocks are due to fracturings;

c. the deep fractures give a possibility for the subcrustal rock melts to rise from the depth toward the surface and thus to create individual magma chambers within the crust, that are aligned linearly;

d. such linear belts show themselves by the presence presence of linear heat flow anomaly belts;

e. volcanic activity therefore is likely within such broad seismic belts and particularly within such heat flow anomaly belts.

The order of ideas, from point a to e makes the supposition likely that the critical area denoted by isv in Figs. 204/4 and 204/5 is a submarine volcano.

In conclusion, the following statements can be made:

(1) The pumice masses that were observed at the central part of Ninety East Ridge could not have come from Krakatau volcano. Neither oceanic currents nor winds could carry these pumices from Krakatau to the sites where they were observed.

(2) Consequently, it must be supposed that the pumices in question came into being in situ.

(3) Laboratory experiments, carried out by Brun at the beginning of this century, demonstrated that the origin of pumice is independent of its place. Therefore pumice can originate not only in shallow, but in deep water, too. This is proved by two examples in the Atlantic Ocean, when pumice was observed over submarine eruptive centers, the depth of which in one case was some 1500 m and in the other case was at least 2000 m or even much more.

(4) Near the point denoted by a in Fig. 204/2 there is a submarine elevation the top of which is lying at a depth of about 2500 m. Point a is a place on which floating pumices were seen three times. Southwestward of it there is another point, symbolized by b, on which pumice was also observed. This flat submarine elevation is regarded to be the submarine volcano from which the pumices observed originated in 1879 and 1883, in each case preceding the paroxysmal phase of the Krakatau eruption. Note that during and after the paroxysm no floating pumices were seen on these sites.

(5) The geographical coordinates of the center of the submarine elevation in question are: 6°05' S, 89°10' E. It is located in the axis of the Ninety East Ridge near but a little northward of its central part. Strictly speaking, however, the submarine elevation belongs to the northern (active) segment of the Ridge.

(6) The inferred submarine volcano is located within a belt of high heat flow anomaly. Southeast of it there is a particular "hot spot" with a value of 7.61 HFU - the greatest heat flow anomaly within the area extending from 73° E to 105° E, and from 10° N to 31.5° S. The zone in question (belt I) is the axis of the broad seismic belt, between points b and c (see in Fig. 204/5). The seismically active long and wide streak from point a through b as far as c is regarded as a zone of weakness. The shocks (all of shallow origin) are the consequences of fracturing processes within the oceanic lithosphere.

(7) Within such a zone of weakness there is a possibility for the origin of deep fractures along with the rock-melts can easily emerge from the depth towards the surface, creating thus a linear chain of (shallow) magma chambers (probably within the oceanic crust).

(8) One of these magma chambers led to the submarine outbursts in 1879 and 1883, the surfical signs of which were the pumice masses observed.

(9) There is a possibility for further submarine eruptions along the same belt of heat flow anomaly, perhaps in the form of rather slow lava flows on the bottom of the ocean rather than violent, explosive eruptions; particularly at point beta, where the abnormally high heat flow value has been observed.

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205. 1880 July--Unnamed submarine volcano, Azores

Neumann van Padang (1938) has mentioned a submarine eruption and a new island with a diameter of 155 m. No exact coordinates were given; it appeared at a distance of 9 km from Sao Jorge, the latter being at 38°30'N, 28°00'W (Sapper 1927).

206. 1880--Veteran, Cochin China

A submarine eruption probably occurred in this year (MacDonald 1972). Underwater activity may result in the belief that a reef existed here (Neumann van Padang 1953).

?

207. 1881 July -- Submarine volcano, Campi Flegrei del Mar di Sicilia

West of Pantelleria a small island was created by submarine activity (van Padang 1938). Location: 36°51'N, 11°55'E.

208. 1881 -- Nameless submarine volcano, Melanesia

A submarine eruptive center is reported at 18°45'S, 169°11'E by MacDonald (1972), no further details are known.

209. 1881 -- Sao Jorge, Azores

New island that soon disappeared (Sapper 1927).

210. 1882 -- Bogoslof, Aleutian Islands

Steam was observed from the sea, north of Ship Rock (Latter 1979).

211. 1883 March 28 -- Tuluman, Admiralty Group, Melanesia

Fisher (1957) noted a submarine eruption. No further activity was observed until 1953 June 27 when the first phase of a new cycle began.

212. 1883 July 11-12--Georgiana, Ninety East Ridge, Indian Ocean

See item 204.

213. 1883 August 1--Georgiana, Ninety East Ridge, Indian Ocean

See item 204.

214. 1883 August 11--Georgiana, Ninety East Ridge, Indian Ocean

See item 204.

215. 1883 August 17--Georgiana, Ninety East Ridge, Indian Ocean

See item 204.

216. 1883 August 18--Georgiana, Ninety East Ridge, Indian Ocean

See item 204.

217. 1883 August 19--Georgiana, Ninety East Ridge, Indian Ocean

See item 204.

218. 1883 August 26 -- Krakatau, Sunda Strait (Fig. 218/1)

The great and well-known catastrophe that caused the deaths of 36,417 persons (Sapper 1927) is treated in very detailed form in almost every volcanological and geological textbook. Therefore we do not wish to deal with the volcanological events here in detail and shall confine ourselves primarily to the subject of tsunamis, quoting some authors, following the order of the year of publication of their works. A very vivid and interesting description on all of the events is to be found in Lane (1966). As a matter of fact, there was more than one tsunami: the first one on August 26, the second on August 27, and after these further oscillations of the sea were observed. These latter phenomena were due to atmospheric pressure waves rather than the collapse of the volcanic mount (Ewing and Press 1955). In the following we shall speak about the <u>first</u> and <u>second</u> tsunami as well as about <u>further oscillations</u>. Within one tsunami the number of waves was not necessarily only one. For instance:

Heck 1947, p. 280): "Three waves following eruption of Krakatoa. On Java shore, height was estimated at from 100 to 135 feet at Mera, 50 feet at Tyringen, and 33 feet at Anjer. On Sumatra shore, height rose to 80 feet; at Telok Batong, 72 feet; at Batavia 17 feet." (<u>Second</u> tsunami).

Berninghausen (1966, pp. 71-73): "1883. August 26. Sunda Strait (Selat Sunda 6°00'S, 105°45'E). Several explosive eruptions of Krakatau generated waves which destroyed near shore houses at Tjaringin (6°21'S, 105°49'E) and Merak (5°44'S, 106°00'E) in Java and Telukbetung (5°27'S, 105°16'E) on Sumatra." (<u>First</u> tsunami).

"August 27. Sunda Strait. Explosive eruptions of Krakatau at 0100, 0630 and 0730, local time, generated waves which destroyed or damaged Sirik (6°07'S, 105°53'E) and Anjerlor (6°05'S, 105°55'E) on Java and Telukbetung on Sumatra. At 1000 local time, 0358 GMT, a fourth explosive eruption of Krakatau generated waves, with local heights up to 100 feet, which devastated the adjacent shores of Java and Sumatra. Waves were reported from South Africa, Arabian Peninsula, points on both sides of the Indian Peninsula, Ceylon, Sumatra, Java, Australia, and various islands in the Indian Ocean as well as from locals in the Atlantic and Pacific. The table (see below) gives a summary of the reports on the tsunami in the Indian Ocean." (<u>Second</u> tsunami and <u>further oscillations</u>).

Herewith we are enclosing the original table from the above cited paper of Berninghausen (1966, p. 71):

Table 218/1. Tsunami generated by the 27 August 1883 eruption of Krakatau

Places Reporting the Wave	Latitude	Longitude	Distance from Krakatau (Nautical Miles)	Time of Arrival of First Great Wave (GMT)	Height of 1st Great Wave (Inches)	Height of Maximum Wave (Inches)
Sunda Strait						
Krakatau....................	06°06 S.	105°25 E.		0258		1,200 ±
South coasts of Sumatra and Java						
Bengkunat Bay..............	05°37 S.	104°18'E.	90			Slight
Palabuhan Ratu (Wijnkoops baai)..............	07°05'S.	106°27'E.	147			60
Teluk Sanbat...............	04°50'S.	103°20'E.	160			72
Mana.......................	04°28'S.	102°54'E.	210			36
Pino.......................	*	*	215			84
Bengkulu...................	03°48'S.	102°15'E.	265			36
Tjilatjap..................	07°44'S.	109°01'E.	330	0958		72
Mukomuke...................	02°35'S.	101°08'E.	370			48
Painan.....................	01°21'S.	100°34'E.	455			108
Padang.....................	00°58'S.	100°22'E.	490	0644		Noted
Cocos (Kelling) Islands......	12°00'S.	96°50'E.	623			50?
Andaman Islands						
Port Blairt................	11°36'N.	92°45'E.	1485	0747	7	
Southwest coast of Ceylon						
Galle......................	06°02'N.	80°13'E.	1678	0754		48
Colombo....................	06°56'N.	79°51'E.	1760	0911		44
East coast of Ceylon						
Arugam Bay.................	06°51'N.	81°50'E				Noted
Batticaloa.................	07°43'N.	81°42'E.				36?
Trincomalee................	08°34'N.	81°14'E.	1694	0805		40?
Mullaittivu................	09°16'N.	80°49'E.				Noted
Point Pedro................	09°50'N.	80°14'E.				24?

Table 218/1. (continued)

Places Reporting the Wave	Latitude	Longitude	Distance from Krakatau (Nautical Miles)	Time of Arrival of First Great Wave (GMT)	Height of 1st Great Wave (Inches)	Height of Maximum Wave (Inches)
East Coast of India						
Negapatam†	10°46'N.	79°50'E.	1840	0920	11	12
Madras†	13°05'N	80°17'E.	1905	0912	4	4
Visakhapatnam	17°42'N.	83°18'E	2012	0949	6	6
False Point†	20°18'N.	86°48'E.	2068	1049	8	12
Dublat†	*	*	2116	1204	8	8
In River Hoogly						
Diamond Harbor†	22°12'N.	88°12'E.	2151	1414	8	8
Kidderpore†	22°32'N.	88°19'E.	2194	1619	4	4
West Coast of India						
Beypore†	11°11'N.	75°49'E.	2150	1046	8	14
Bombay†	18°45'N.	72°50'E.	2634	1359	5	7
West Pakistan						
Karachi†	24°52'N.	67°03'E.	3210	1412	10	15
Arabian Peninsula						
Aden†	12°46'N.	45°01'E.	3804	1449	4	5
South Africa						
Port Alfred†	33°36'S.	26°54'E.	4632	1522	17	19
Port Elizabeth†	33°58'S.	25°35'E.	4687	1610	16	30
Seychelles Islands						
Mahe Island	04°40'S.	55°28'E.	2983	1218		12
Cargados Carajos						
Avocaire Island	16°36'S.	59°38'E.	2753	1101		Noted
Rodrigues Island						
Mathurin Bay	19°40'S.	63°25'E.	2579	1006		24
Muritius						
Port Louis	20°10'S.	57°30'E.	2913	1025		18
West coast of Australia						
Cossack	20°42'S.	117°12'E.	1107			60
Geralton	28°46'S.	114°38'E.	1456			72
Ashburton River	21°40'S.	114°56'E.	1080			Noted
Rottnest Island	32°00'S.	115°30'E.	1653			18

*This cannot be located on available gazetteers, maps, and atlases.
†Records from tide gages.

Berninghausen (1968, p. 32, and 43, respectively): "1883. Aug. 27 and 28. Atlantic Ocean, English Channel: Waves attributed to the explosive eruption of Krakatau in the Sunda Strait between Java and Sumatra on the 26th were recorded on tide gages (gauges - note by Hedervari) throughout the world." The resume of the tide gage records in the Atlantic is given in the next table:

Table 218/2. Tide gage records of Krakatau Wave in the Atlantic

Location	Latitude	Longitude	Distance from Krakatau (N utical miles)	Commencement of disturbance G.M.T. (da /hr/min)	First great Wave G.M.T. (day/hr/min)	Height above normal (in.)	Height of max. Wave (in.)
Kravatau Cape H	06°06'S.	105°25'E.	...	27/02/58	...	...	...
Bahia Orange	55°32'S.	68°01'W.	Pacific 7,520 via Indian 7,818	27/18/52	29/09/29	5	5

Table 218/2. (continued)

Location	Latitude	Longitude	Distance from Krakatau (N utical miles)	Commence-ment of disturbance G.M.T. (da'/hr/min)	First great Wave G.M.T. (day/hr/min)	Height above normal (in.)	Height of max. Wave (in.)
South Georgia							
Port Moltke	54°31'S.	35°54'W.	6,676	27/16/27	27/16/55	5	7
Panama							
Colon	09°22'N.	79°54'W.	11,470	...	27/21/50	7	...
Europe							
Socoa	43°24'N.	01°39'W.	10,900	27/05/52	28/04/57	2	3
Rochefort	45°56'N.	00°59'W.	10,900	28/07/44	28/09/24	2	3
Devonport	50°22'N	04°11'W.	11,040	28/06/20	28/10/45	4	4
Cherbourg	49°39'N.	01°39'W.	11,096	28/09/26	28/09/26	1	2
Portland	50°33'N.	02°26'W.	11,097	...	26/10/15	1	1
LaHavre	49°30'N.	00°08'E.	11,160	28/11/33	28/11/33	1/2	1

Note that the data in this Table refers to the further oscillations.

Berninghausen (1969, p. 292): "1883. Aug. 26. Indonesia, Java and Sumatra. Waves generated by the explosive eruption of Krakatoa in the Sunda Strait were reported from stations throughout the world. Waves estimated at from 30 to 40 meters (100 to 130 feet) in height were reported from the Java shore of the strait while 24 meter (80 feet) waves were reported from the Sumatra shore. The following list gives information on waves which were noted along the northern coast of Java."

Table 218/3.

Place		Distance from Krakatoa Miles	Wave height (meters)	(feet)
Bantam	(06°03'S., 106°09'E.)	50	2.0	6.0
Lontar	(05°58'S., 106°18'E.)	55	2.3	7.5
Kramat	(06°16'S., 106°38'E.)	77	3.4	11.0
Tandjungpriok	(06°06'S., 106°52'E.)	100	2.0	6.0
Tjilintjing	(06°06'S., 106°56'E.)	102	0.6	2.0
Rambatan*		184	0.6	2.0
Djapara	(06°35'S., 110°39'E.)	310	0.5	1.5
Udjung Pangkah	(06°35'S., 112°23'E.)	440	0.02	0.6
Surabaja	(07°15'S., 112°45'E.)	465	0.02	0.6
Karang Kleta*		497	0.02	0.8

(Evans and Wharton 1888, Heck 1947, Verbeek 1886)

*Cannot be located in available gazetters.

These data refer to the second tsunami.

For the first tsunami Iida et al. (1972) gave the following report:

"1883. Aug. 26. 17:07 (local date and time of tsunami generation or, if source unknown, of observation 16.7°S, 105.4. Krakatoa volcano explosions. Generating area: Sunda Strait. Place of observation: Indonesia, Sumatra-Telok Batong, Java-Merak, Anjer. Height: 1.5 (meter). Effects and remarks: camp swept away."

For the second tsunami and the further oscillations the data are given in the following Table:

Table 218/4.

Date	Place of observation	Height (meters)	Effects and remarks
Aug. 26-27	Japan, Honshu-Sagami, Shikoku-Satsuma	very small	The small waves observed in the Pacific, as well as in other oceans, were generated by atmospheric pressure waves resulting from the major Krakatoa explosion and do not represent the true tsunami observed in the vicinity of the Sunda Strait. Few authors have noted that more than one tsunami was connected with the Krakatoa explosion. No magnitudes have been assigned to the Krakatoa tsunamis because this mode of generation was different from that assumed in the definition of tsunami magnitudes.
	Australia, Sydney	<0.1	
	New Zealand	0.3	
	Hawaiian Islands, Oahu-Honolulu	0.24	
	Alaska, Kodiak	0.1	
	California, San Francisco	0.1	
Aug. 27 01:42 05:30 06:44 10:02	Sumatra-Telok Batong, Java-Sirik, Java-Anjer, Sumatra	10	Village submerged. Almost entirely swept away. Lower part of town (probably Java-Anjer -- author) overwhelmed. Major explosion, 8 km^3 of volcano blown away (according to other sources, 18 km^3 -- author). All towns and villages on Sunda Strait destroyed. Warship ("Berouw", a Dutch one -- author) carried 3 km inland to 10 m elevation. All towns and villages on Sunda Strait destroyed.
Aug. 27 02:59	Sumatra-Talok Batong, Vlakke Hock	22 15	
	Java, Tyringen	15-20	
	Merak	35	
	Batavia	2.4	
	Surabaya	0.2	

Table 218/4. has been compiled after Iida et al. (1972).

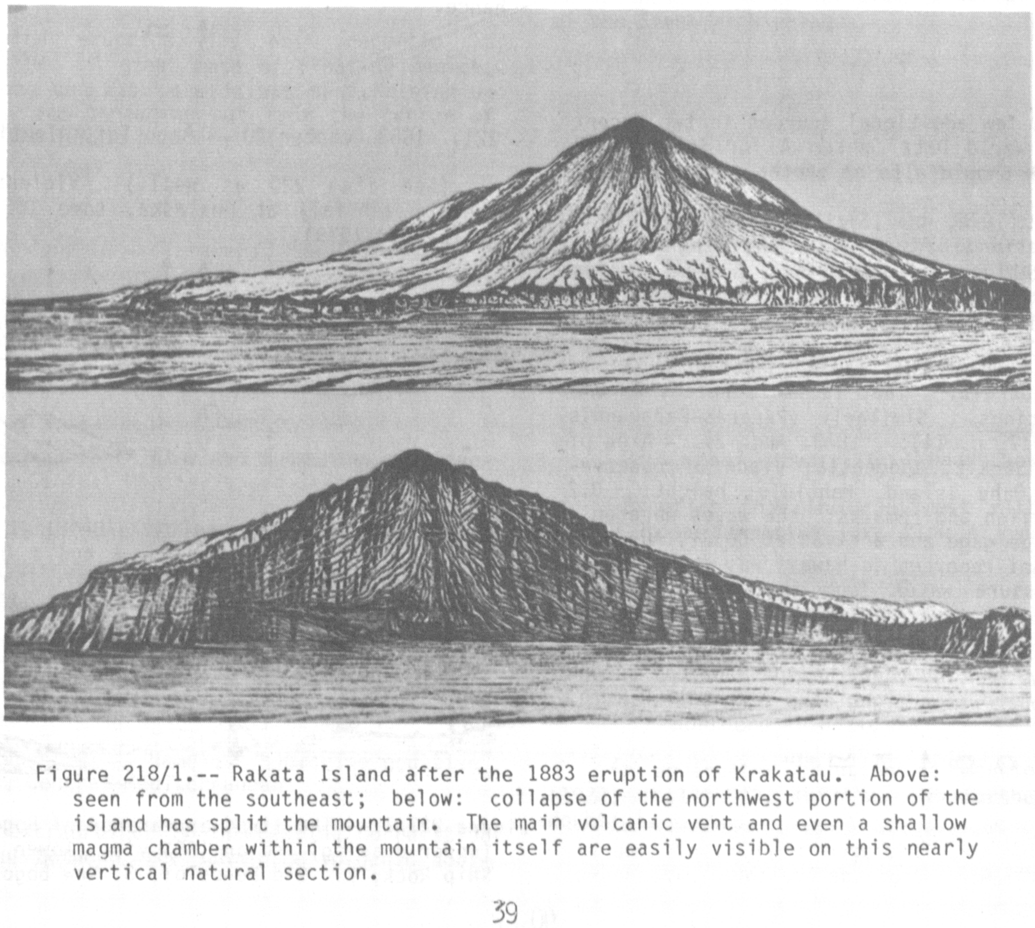

Figure 218/1.-- Rakata Island after the 1883 eruption of Krakatau. Above: seen from the southeast; below: collapse of the northwest portion of the island has split the mountain. The main volcanic vent and even a shallow magma chamber within the mountain itself are easily visible on this nearly vertical natural section.

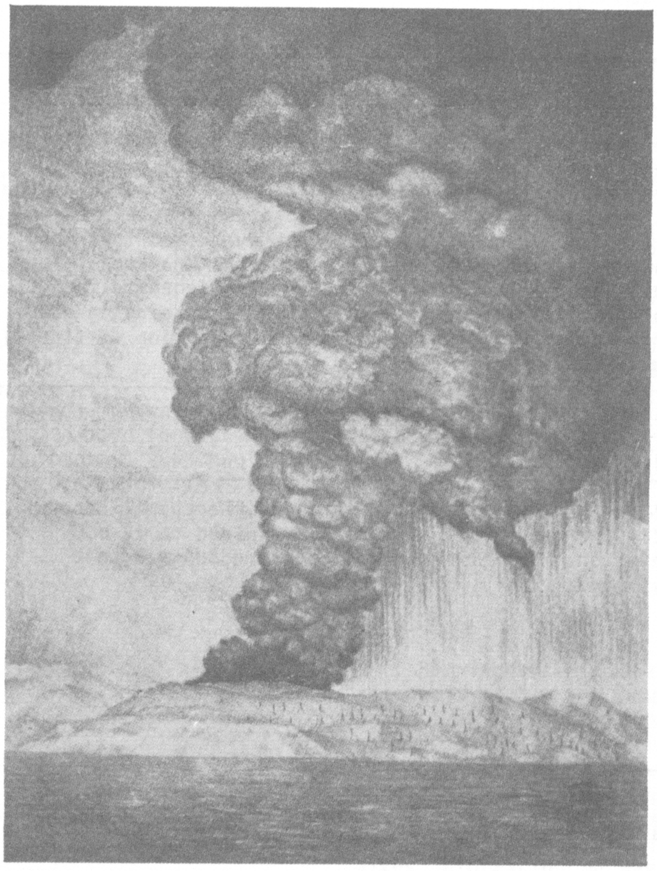

Figure 218/2.-- Old painting about eruption of Krakatau in 1883. After Mercalli.

There are a few additional sources in two recent publications of World Data Center A for Solid Earth Geophysics, which should also be quoted. Accordingly:

Cox et al. (1976, p. 13): "1883. Aug. 17. - Place of observation: Alaska, Kodiak; height: 0.1 (meter); observation and remarks: small waves arriving 27 August sometime between 18:00 and 23:00 were generated by atmospheric pressure waves resulting from the explosion of Krakatoa, and were not associated with the tsunami that caused destruction along shores of Sunda Strait." That is, this refers to the further oscillations. Similarly (Pararas-Carayannis and Calebaugh 1977, p. 14): "1883. Aug. 27. - Area of origin: Sunda Strait, Indonesia; place of observation: Hawaii, Oahu Island, Honolulu; height: 0.2 (meter); observation and remarks: the waves were only detectable by tide gage and arrived at 00:31, Aug. 27. (The small tsunami recorded in Hawaii was generated by atmospheric pressure waves from the major Krakatoa eruption. The only true tsunamis were generated and observed in the vicinity of Sunda Strait.)"

Finally, we mention that the speed of the second tsunami in the open water might have reached 700 km/h.

219. 1883 September 27 -- Bogoslof, Aleutian Islands

Birth of lava dome known as New Bogoslof, north of Ship Rock (Latter 1979). Submarine eruption, and as a consequence an andesitic lava dome came into being. Later on a subaerial crater was formed (Mercalli 1907). Appearance of a new tabular mass of lava from the sea. Grewingk = Fire = New Bogoslof. Explosions, bombs, and debris joined Ship Rock and Castle Rock to form a single, elongated island (Bullard 1968).

220. 1883 February 6 -- St. Augustine, Alaska

Explosive eruption, accompanied by tsunami with a height of 9 m (Henning et al. 1976) or 10 m (Sapper 1927), respectively. It was observed at Kenai Peninsula, Port Graham (Cox et al. 1976), and on the Aleutian Islands (Hech 1947) as well. The tsunami magnitude is assigned as 3? (Iida et al. 1972) which corresponds to an energy of $1.58 \cdot 10^{23}$ ergs. According to Sapper (1927), rumblings, pumice-fall, ash-fall, bombs, lapilli, and "flames" were observed, and "the mount split in two". The eruption has been designated very powerful and paroxysmal by Hantke (1979). Note: Mercalli (1907) has called attention to the interesting fact that the great explosive outbreak of St. Augustine occurred almost simultaneously with the eruption of Bogoslof (see item 221). May it be that these two eruptions were really connected in an unknown way with each other? In our opinion a physical correlation between these two volcanoes is extremely unlikely; consider the very great distance between these eruptive centers. Thus their almost simultaneous activity is, in all probability, due to chance.

221. 1883 October 20 -- Bogoslof, Aleutian Islands

(See item 220 as well.) Violent explosive outburst, ash-fall at Unalaska, some 100 km to the east (Latter 1979).

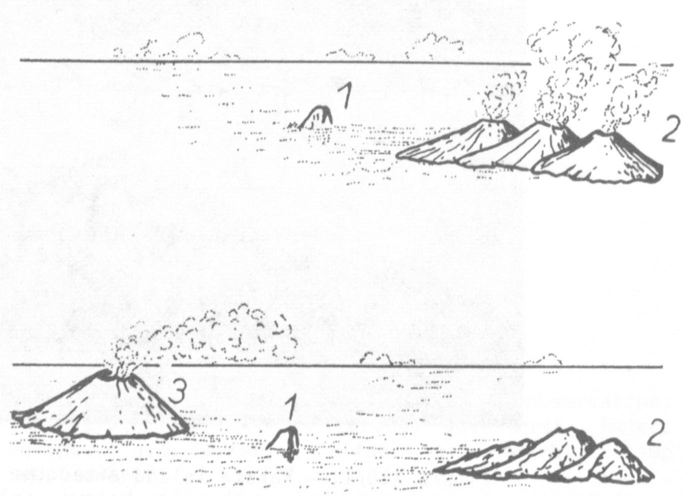

Figure 221/1.-- The first appearance of Bogoslof in 1796 (upper drawing) and an 1883 view (lower drawing). 1. Ship Rock; 2. Old Bogoslof; 3. New Bogoslof.

222. 1884 December 29--Unnamed submarine volcano, northern Atlantic

The water suddenly became boiling and seething over a region 8 to 10 km. The sea surface at places was thrown up to a height of 0.6 m above the normal level. It might have been a real eruption, because of the relative proximity of a seamount (van Padang et al. 1967). The coordinates of the seamount in question are 48° 17.5' N, 35° 22' W, and the event was observed at 49° 00' N, 34° 30' W.

223. 1884 (?) -- Eldey, Iceland

Submarine activity, no details (Berninghausen 1964).

224. 1885 October 11 (or October 14) - 1886 October -- Falcon Island, Tonga Volcanic Group

New island appeared. In 1886 the volcano was still in eruption (Richard 1962). According to Sapper (1927) the new island came into being on October 14, and 4 days later submarine activity was observed again. Activity was noted in the next year also, when the island reached a length of 2600 m and a height of 50. In 1887 it was 90 m high. Disappeared in 1898, but in 1900 cliffs appeared immediately below sea level ("backs of whales").

225. 1886 March -- Unnamed volcano, Kermadec Kermandec Volcanic Group

A submarine eruption has been reported at 29°11'S, 177°52'W. A great mass of floating pumice, nearly 5 km long and 2.5 km wide was seen, rising up from the depth and spreading out from the center of the mass (Richard 1962).

226. 1886 June 10 -- Tarawera, New Zealand

The great explosive eruption that originated from a regional fissure was - probably - accompanied by base surge (MacDonald 1972).

?

227. 1886 August 17 -- Nameless submarine eruptive center, Central Mediterranean Sea

At 35°54'N, 18°40'E a flame was seen, having had a height of 30 m and a width of 10. The phenomenon soon disappeared. Very doubtful event, mentioned only by Sapper (1927). The sea here is about 4000 m deep and the point mentioned is very far from the known volcanic belts of the Mediterranean Sea.

?

228. 1886 August 27 -- Nameless submarine eruptive center, Central Mediterranean

A really extraordinarily interesting correlation can be surmised between the submarine volcanic activity and the great earthquake; both took place on the same day. According to Sapper (1927) at midnight, not too much after the earthquake (see later) a dense, black cloud emerged from the sea vertically. It had a reddish color. The location of the event was 36°17'N, 21°27'E.

For the earthquake, an erroneous location is given by Giorgetti and Iaccarino (1971). According to them event No. 1091 took place at Messenia: 38°18'N, 15°36'E. The epicentral intensity was at least 10 degrees or even more. It is clear, however, that the Greek town, Messenia, was confused with the Italian town, Messina. The coordinates given above (which would refer to the epicentral location) are, in fact, the coordinates of the Italian Messina (according to The Prentice-Hall World Atlas, New Jersey, 1963: Messina: 38°11'N, 15°34'E; while Messini = Messenie: 37°01'N, 22°00'E).

According to Galanoupoulos (1960, 1960a) the epicentral coordinates were as follows: 37°N, 21°25'E and the intensity of the shock at Messini (or Messinia = Philiatra) was 11 degrees. The shock occurred at about 21h 30m GMT and it had an intermediate focus. In spite of this, a tsunami did occur. "A really great, probably intermediate shock with a very large meizoseismal area on the western coast of Messenia, was followed by a tsunami observable as far away as Smyrna." (Galanopoulos 1960, p. 378). The same data are repeated by Ambraseys (1962), as well as Karnik (1971). Three towns: Philiatra, Ligudistra, and Koroni and 123 villages were almost completely destroyed. Richter magnitude: 8.4.

In all likelihood the submarine eruption was directly triggered by this tremendous shock. Note that the place mentioned as the probable site of the volcanic phenomenon, can be found south of Peloponnesos, rather far from the known volcanic chain of the Greek archipelago.

229. 1886 -- Metis Shoal, Tonga Volcanic Group

Submarine activity. The rock that came above the level of the sea as a result of the underwater eruption in 1858 (see item 188), was 122 m high and it occasionally has been very active (Richard 1962).

230. 1887 January 16 -- Mauna Loa, Hawaii

Eruption from the southwest rift zone, accompanied by a submarine lava flow of some 153 million m^3 (MacDonald 1955).

231. 1887 April 1 -- Unnamed submarine volcano, Northern Atlantic

An underwater eruption is mentioned by Sapper (1927) at 17°38'N, 46°34'W. No further information; doubtful.

?

232. 1887 -- Falcon Island, Tonga Volcanic Group

The new island (see item 224) has reached a length of some 87 m and is evidently still in further - although slow - development (Richard 1962). (See 1889 as well.)

233. 1887-1890 (between these years) -- Bogoslof, Aleutian Islands

Disappearance of Ship Rock (Latter 1979).

234. 1888 March 13 -- Ritter Islands off the Northeast Coast of New Guinea

The eruption was somewhat similar to that of Tambora in 1815 and Krakatau in 1883: on the dawn of March 13, most of the volcanic mount was disintegrated by a terrible explosion (Fisher 1957), that was followed by a great and powerful tsunami. Prior to the eruption it was a cone some 800 m high, but the catastrophic event caused removal of most of the subaerial portion of the mount, in all likelihood by a collapse-process (Center for Short-Lived Phenomena, Report No. 1507, 1972).

Heck (1947) gave March 12 for the day of occurrence of the tsunami. Generally, however, March 13 is accepted. The seismic sea wave engulfed the north coast of New Guinea and it was observed in New Britain as well. It caused great damage and some loss of life. Heck does not mention volcanic eruption. The tsunami magnitude was assigned as 2? by Iida et al. (1972); the corresponding energy amounts to $3.98 \cdot 10^{22}$ ergs. The maximum height of the waves was 12 m.

235. 1889 September 6 (or September 9?)--Banua Wuhu, Sangihe Islands

Berninghausen (1969) gave the date of the event as September 6, but in other sources (Neumann van Padang 1951, van Bemmelen 1970) we find September 9. It is likely, however, that the two eruptions are the same. There is some confusion with the eruption of Ruang--see item 236. However, Ruang's outbreak is not mentioned by the Catalogue of Active Volcanoes of the World (Neumann van Padang 1951). According to Berninghausen (1969) the waves were relatively small ones, only 1.5 m in height at Taroena on the Sangihe Islands. The waves washed up many dead fishes. Neumann van Padang (1938) has mentioned the birth of a new island, having had a height of 50 m at the most. The activity ended in 1895. On September 6 a shock was felt that was probably a tectonic one.

236. 1889 September 9--Ruang, Sangihe Islands

As mentioned in item 235, this alleged eruption is often confused with the activity of Banua Wuhu. According to Iida et al. (1972) a tsunami accompanied the eruption of Ruang. It had a magnitude of 1?, which corresponds to an energy of 10^{22} ergs. The eruption was in progress when the tsunami took place. The outbreak is doubtful, however, as it is not mentioned by Neumann van Padang's Catalogue of Active Volcanoes of the World (1951). It is noteworthy, furthermore, that Heck (1947) also mentioned the event but erron-eously gave 1899 September 8 instead of 1889 September 9 as the date.

?

237. 1889 -- Kita-Iwo-zima, Izu-Mariana Islands

The water was ejected to a height of 100 m; the activity stopped after the earthquake of that year. Black mud and ash were thrown up from the submarine eruptive center. Sapper (1927) has mentioned a submarine outbreak from this area but without giving the date of the event's occurrence (Kuno 1962).

238. 1889 -- Unnamed volcano, Tonga Volcanic Group

This submarine volcano is located between Tongatapu and Fonua Fo'ou, the latter name is a synonym for Falcon Island. No further data for the exact site are given. Discolored water, containing volcanic matter (some kind of fine particles) was reported (Richard 1962). The event is a little doubtful.

?

239. 1889 -- Falcon Island, Tonga Volcanic Group

In this year the island (see items 224 and 232, respectively) was 2 km long and 1.6 km wide, with a maximum height of almost 47 m at the southern end. It consisted of loose ashes and cinders (Richard 1962).

240. 1889 -- Metis Shoal, Tonga Volcanic Group

The rock which came into existence in 1858 (see items 188, 201, and 229, respectively), in 1889 was about 90 m across and some 20 m high (Richard 1962).

241. 1890 February -- Bogoslof, Aleutian Islands

Submarine outbreak (Mercalli 1907). Ash on Fire Island, which was in a fumarolic stage until about 1896 (Latter 1979).

242. 1891 October 17 - October 25 - Foerstner (Phlegraean Fields of the), Sicily Sea

This submarine eruption point is also known as "Bank NNW of Pantellaria". Explosive eruption with emission of gases and ejection of internally incan-

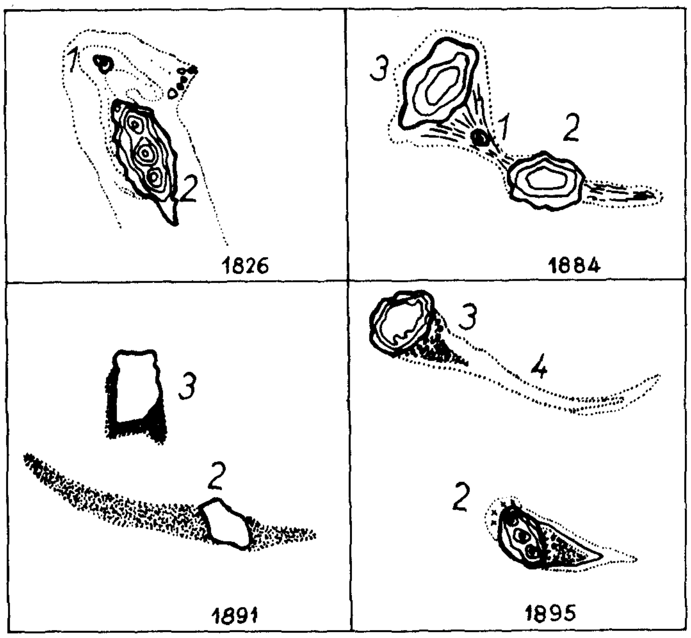

Figure 241/1.-- Development of the Bogoslof group. 1. Ship Rock; 2. Old Bogoslof; 3. New Bogoslof; 4. Strip of land that is dry at ebb-tide. (From Sapper)

descent fragments along the northwest submarine slopes of the island. Earthquakes and upward motions of the island as a whole preceded and accompanied the event (Imbo 1965).

⊼ ↑

243. 1891 December -- Unnamed volcano, Campi Flegrei del Mar di Sicilia

Only uncertain references are available about a submarine eruption south of Pantelleria (Imbo 1965).

⊼ ?

244. 1892 June 7-8--Awu, Sangihe Islands

A tsunami occurred with a magnitude of 1? (Iida et al. 1972) as a result of the Awu eruption, but no details are known. The eruption itself is assigned as a great one by the Catalogue of the Active Volcanoes of the World (Neumann van Padang 1951). Sapper (1927) mentioned that 1,532 persons lost their lives. It is supposed that the tsunami was caused by nuees ardentes entering the sea.

O ↑

245. 1893 (more likely before this year)-- Emperor of China, Banda Sea

Submarine explosions? The existence of this volcano, first mentioned in the Catalogue of Active Volcanoes of the World (Neumann van Padang 1951) was recently doubted by Jezek (1978) and debated by Neumann van Padang (1978). The situation is the same with Yersey (Lesser Sunda Islands), Nieuwerkerk (Banda Sea) as well as with a nameless submarine volcano in the region of the Sangihe Islands. The matter of the debate is very interesting and very pertinent to our subject; furthermore as the periodical "Berita" of the Indonesian Geological Survey (Direktorat Geologi) is not available for all of the readers, it seems to be reasonable to give here a summary of the views of Jezek and Neumann van Padang.

Neumann van Padang (Berita, 10, 17, pp. 198-199, 1978) has written:

> In "Berita" v. 10 (1978), n. 13, p. 150, c.2. I read that Jezek doubts the existence of submarine volcanoes Nieuwerkerk and Emperor of China. But unfortunately the motives of his doubts were not mentioned.
>
> I am of the opinion that Boerema's way of this thinking was logical and therefore correct. He wrote (1929, p. 919): "On the sea chart of islands and channels East of Java 1:1,000,000, edited in 1893 three coral reefs were inserted with the names:
>
> Nieuwerkerk reef..........124°43'E, 6°39'S
> Emperor of China reef.....124°17'E, 6°44'S
> and
> Yersey reef...............123°57'E, 7°32'S"
>
> Krusinga (1938, p. 955) communicated that according to J.C.H. Luijmes, Chief of the Department of Hydrography, Nieuwerkerk was a ship wrecked in 1742 about 60 km northerly, and Emperor of China another ship wrecked at about the same place in 1852.
>
> On September 24, 1925, a ship sailing at 6°40'S and 124°41'E observed at a distance of about 2 km turbulent water. The extension of the surf was estimated to be half a mile. The place was considered to be the same as that of the Nieuwerkerk reef. The disturbance of the water was the same as may be seen on reefs during calm weather and light swell. This report induced the Marine Department of the Netherlands Indies to make research into that region.

Soundings were done by the surveying vessel H. M. Tydeman and the submarine K. III. in May and by the submarine K. X in November 1926. However none of the vessels found a depth less than 2300 m. Therefore the reefs were expunged on the sea chart edition of 1927.

By inserting the different tracks on tracing cloth it became clear that a 1000 m high mountain ridge rose on the sea bottom with a depth of 4200 m. The summit with rather steep slopes had a height of 2000 m. The configuration of the sea bottom made it sure that surf on a coral reef was impossible and that the disturbance of the sea water observed on this spot could only be caused by the activity of a submarine volcano. This elucidated also that surveying vessels could not localize the supposed surf when the activity had subsided.

There was still another indication that we had to do with a submarine volcano. In February and March 1927 thousands of fishes, turtles etc. were washed ashore on the Islands of Alor and Lomblen situated at about 100 miles south and southeast of Nieuwerkerk. This phenomenon could only be caused by a submarine eruption.

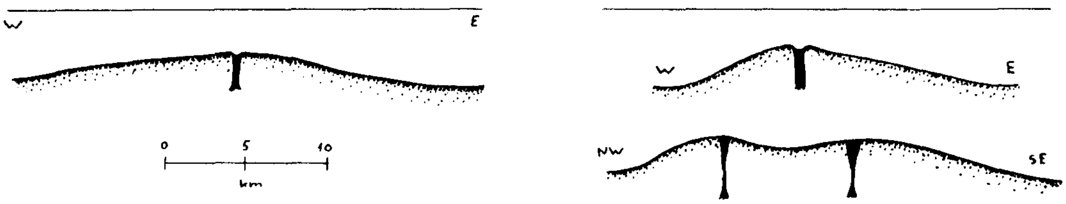

Figure 245/1.-- Left: Section across Emperor of China. Right: sections across Nieuwerkerk (after Neuman van Padang).

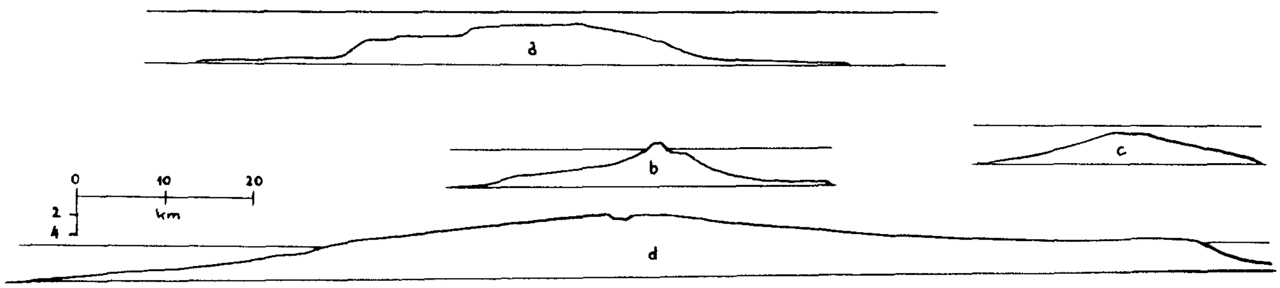

Figure 245/2.-- Sections across some volcanoes (after Menard). a: Guyot, 290° N, 155° E; b: Ganung Api, Eastern Indonesia; c: Jasper seamount; d: Mauna Loa with its top-caldera (NE-SW section).

The soundings also gave indication of a submarine mountain of 1800 m height at the place of the "Emperor of China" reef.

In November 1929 Stehn (1929, p. 149) gave the volcano Nieuwerkerk the number 107, and Emperor of China the number 108.

That we have to do with submarine volcanoes was affirmed by the soundings of the Snellius Expedition. Van Riel (1934, on plate 9) showed that Emperor of China was a submarine mountain rising nearly 1500 m above its surroundings, having a summit which was 2850 m below sea level. Nieuwerkerk was a NNW - SSE stretching submarine mountain with two tops at a mutual distance of more than 7 km, rising about 1800 m and 1900 m above the bottom of the sea. The NW summit I at 6°36'S and 124°40'E was 2285 m, the SE summit II at 6°39'S and 124°43'E was 2325 m below the level of the sea. They were separated by a 600 m deep saddle.

Neumann van Padang (1938, p. 80 fig. 4. and 5.) published the chart that van Riel made of this part of the Banda Sea and cross sections through these two mountains. The place of the southern top corresponded with that of the so called Nieuwerkerk reef on the chart of 1893. (See also Neumann van Padang 1951, pp. 212-216.)

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van Riel, P.M., 1934: The bottom configuration in relation to the flow of the bottom water, The Snellius Expedition, v. 2, Pt. 2, Plate 9.

This paper of Neumann van Padang, which was described here fully and literally, was supplemented by a note from the editor (K. Kusumadinata) as follows:

"Note from the Editor: Jezek doubts the existence of the submarine volcanoes in the Banda Sea as the data were not very reliable. We do agree with him in this case. In our opinion if both volcanoes exist -- they must receive their magma supply from a very great depth, since the primary magma chamber must be lying more than 500 kilometres beneath the surface. This value seems to be very improbable."

We do not share the opinion expressed by the editor. At first, the profiles of the oceanic bottom (see Fig. 245/1) provide unquestionable proof for the assertion of van Padang. According to him we have here typical volcanic forms. These features resemble very much volcanic shields with a top-crater or caldera, similar to - for example - Mauna Loa of Hawaii (see Fig. 245/2). Secondly: we are familiar

with volcanic regions in the case of which the depth of primary magma chambers is surprisingly high. E.g., we found some 330 km for Vesuvius, 380 km for the Phlegraean Fields and 405 km for Ischia (Hedervari 1974-75); furthermore, as pointed out by Ninkovich and Hays (1971), the Indonesian volcanoes Batu Tara (north of Flores) and Muriah (on the northern coast of Java), which were active in the Pleistocene, are 300-400 km above the Benioff zone, and the volcano Ullung-do from the Sea of Japan and some plateau basalts from Korea and Manchuria are about 600 km above the seismic zone. In terms of the accepted model for the deep structure of island arcs (Minear and Taksoz 1970, Toksoz et al. 1971), local melting just beneath the active volcanos begins along the upper surface of the downgoing, usually oceanic lithospheric slab, and hence, primary magma chambers are formed at the upper edge of the seismic zone known also as Benioff zone which shows the position of the downgoing slab. Therefor, we cannot accept the counter-argument, mentioned above, according to which "if both volcanos exist -- they must receive their magma-supply from a very great depth, 500 km or more which appears to be improbably high." In the light of the examples, summarized above, such a great depth is not improbable at all.

In his answer to Neumann van Padang's paper, cited above, Jezek has written as follows (Berita 10, 20, pp. 254-256, 1978):

"Following is a discussion of observations used in classifying the submarine volcanoes:

"1. Disturbed sea water--Neuman van Padang et al. (1967) placed this type of observation in the 'Doubtful' category.

"2. Massive kill of fishes, turtles, etc.--known to occur in areas without any volcanic activity (e.g. 'red tide' occurring off the east U.S. coast; 'El Nino' occurring off the west coast of South America--both known to be caused by biological or hydrological factors) therefore does not document volcanic activity. Due to our poor knowledge of ocean currents in Eastern Indonesian waters in general it is even uncertain where these dead fishes and turtles, found on Alor and Lomblen, came from.

"3. Shipwrecks--without observations of volcanic phenomena made concurrently, in my opinion do not document submarine activity. It is unlikely that s submarine eruption at a depth greater than 2000 m would cause a shipwreck unless it was an exceptionally violent one which would then probably cause large tsunamis etc. recorded over a large area. It is very unlikely that two ships at two different times would be located exactly above the volcano just as the eruption was beginning because if a violent eruption was in progress the ships would avoid the area.

"4. Bottom features--the bathymetry of the southern Banda Sea shows some relief and although volcanic features may be present the lack of bottom samples and/or photographs prohibit unambigous (sic) classification of these features.

"In the Celebes Sea no relief is found in the area of the proposed submarine volcano and approximately 5000 m deep sea floor is present."

I complete this interesting discussion, "Berita" (= Newsletter) has published a note in the November 1978 issue (10, 21, pp. 260-261), in which we can read the following:

In his letter of October 17, 1978, Dr. M. Neumann van Padang . . . writes that Jezek is of course right that disturbed sea water is not always due to an volcanic eruption below sea level. . . . When on September 24, 1925, broken water was sighted by the steamer Volsella at the place where Nieuwerkerk was inserted, exactly on the place where brakers or bubbles was observed earlier, the navigator was of the opinion that the coral reef on the map of 1893 was rediscovered. At the very time nobody was thinking on the possibility of a submarine volcanical outburst.

The 'reefs' Nieuwerkerk, Emperor of China and Yersey (see map 1893) of course were named after the ships which observed phenomena such as breakers of coral reefs. Neumann van Padang regrets not to be aware when it was carried out and by whom. Only at the time soundings were conducted at this place in 1926 depths of more than 2300 m were discovered. Boerema only then arrive to the thought that the 'disturbance of the sea water' must be due to a volcanic outburst.

The thousands of fishes washed ashore might be a proof of Boerema's correct sight. In no case it is contrary to it.

The 'reefs' Nieuwerkerk and Emperor of China were drawn on the map of 1893. In 1930, exactly 37 years later the bottom of the sea was mapped by the Snellius Expedition and only then it appears there were undersea mountains of 1500 and 1900 m in height, their summits were situating on the places of the reefs on the old sea chart . . . This is not quite an accident and according to Neumann van Padang a strong indication proofing Boerema's opinion. In his article in 1938 Neumann van Padang draw transverse sections through these mountains. It became evident that Emperor of China is a singular cone, Nieuwerkerk a double one. These 'reefs' had to be named. According to J. C. H. Luijmes, Chief of the Department of Hydrology, the names of the ships were selected which were wrecked in their surroundings, perhaps stranded on reefs somewhere south of Sulawesi. Nieuwerkerk was the name of a ship wrecked in 1742 about 60 km north of the above mentioned place and Emperor of China was another ship wrecked in 1852. It is evident that these ships have nothing to do with submarine outbursts. The ships were only considered to give the 'reefs' a name. Thus it is clear that Jezek misunderstood.

Concerning the submarine volcano I. 84. or 6,7-5 (the first symbol is the serial number of the volcano in the old catalogue, used by the Volcanological Survey of the Dutch East Indies; the second symbol is the serial number of the volcano in the Catalogue of Active Volcanoes of the World -- note by P. H.) in the Sulawesi Sea, Neumann van Padang writes that he refers to this submarine volcano in 1938 as well as in his Catalogue in 1951, as the Catalogue only aims to mention known data on volcanos concerning 'Name and location,' 'Form and structure,' 'Eruptive activity,' 'Petrography,' as well as 'Bibliography.' It was then not aimed to make critical remarks."

Note: The coordinates of this doubtful submarine volcano are 3°58'N, 124°10'E (or 124°12E) (Neumann van Padang 1938).

In conclusion: The present author accepts the possibility of the existence of Nieuwerkerk and Emperor of China, as submarine volcanos, because the profiles of the oceanic bottom show typical volcanic (shield-volcanic) features. Thus in this case we share the opinion of Neumann van Padang. But the existence of the Yersey volcano is not proven by depth-measurements in so definite a way. According to Neumann van Padang (1951), the Snellius expedition in 1929 established a depth of more than 3,800 m and found a submarine ridge that rises about 600 m from the flat floor of the Banda Sea. This submarine ridge carries two active volcanos: Batu Tara and Api (van Bemmelen 1970). Therefore--states the Catalogue of Active Volcanoes of the World--the conception of the existence of a reef must have been caused by a submarine eruption, the date of which is unknown. That is, although the existence of the submarine volcano known as Yersey is not excluded, it is not proven. Concerning this feature, we are inclined to accept Jezek's opinion. Similarly, the existence of the submarine volcano 6,7-5 is very doubtful. The number "6,7-5" is the serial number of a supposed submarine volcano at 3°58'N, 124°10'E (from the Indonesian volume of the Catalogue of Active Volcanoes of the World).

⊼ ?

246. 1894 April -- Falcon Island, Tonga Volcanic Group

It is estimated that about two-thirds of the new island (see items 224, 232, and 239, respectively) was washed away since 1885, the year of its origin. In 1894 only a low streak of black rocks was present (Richard 1962).

✶↓

247. 1894 July--Banua Wuhu, Sangihe Islands

A 50-m high strip of land was seen--perhaps a new island? Uncertain (Neumann van Padang 1953).

⊼ ? ✶ ?

248. 1894 November 21--Unnamed submarine volcano, northern Atlantic

According to Berninghausen (1968, p. 33), "large waves, possibly caused by submarine volcanic activity in the vicinity of 49°00'N, 34°30'W, were reported from several locales in the Atlantic. Off the west coast of Ireland at 53°09'N, 09°52'W, the ship S.S. Diamond lying-to awaiting daylight to enter port, reported that the wave was heard some time before it was seen and then seemed to be about 40 feet high. The vessel never rose to it but was literally submerged for a time." Note: We regard the submarine activity to be a little doubtful. The place mentioned as the site of the submarine eruptive center lies on the northern part of the Mid-Atlantic Ridge where, of course, submarine volcanic activity is possible. However such basaltic lava flows that are frequent along the rift valley are never accompanied by tsunamis. It appears to be more likely that the observed waves were either due to a strong storm or to a seaquake, rather than to a submarine volcanic eruption. Let us remember that neither the birth of Fayal (Azores, 1957 September 17) nor that of Surtsey (Iceland, 1963 November 14) was accompanied by tsunamis, although both eruptions were extraordinarily strong ones and were accompanied by base surges. It is, therefore, hard to believe that a tsunami would have been associated with a slow, normally explosionless, basaltic lava effusion on the bottom or along the inner slope of the rift valley, when a new island did not come into being.

✶ ? ⋍

249. 1894 December -- Falcon Island, Tonga Volcanic Group

Submarine activity. The island (last mentioned under item 246) was 15 m high again; consequently it had grown since 1894 April (Richard 1962).

⊼ ✶ ↑

250. 1894 -- Metish Shoal, Tonga Volcanic Group

The rock that was born in 1858 (last mentioned under item 240) has been active again (Richard 1962).

⊼ ✶ ↑

251. 1895 (end of the year) -- Banua Wuhu, Sangihe Islands

A temporary island came into existence (van Bemmelen 1970).

⊼ ✶

252. 1895 -- Falcon Island, Tonga Volcanic Group

Submarine activity has been reported by Neumann van Padang (1938).

⊼

253. 1895 or 1896 -- Thompson Island, Southern Atlantic

In the following we list a summary of the supposed events given by Baker (1967) and Lamb (1967, 1970, 1971), and an explanation for the lack of tsunami data as well as for the mode of the annihilation of the island (Hedervari 1981b).

The existence of Thompson Island was first claimed by Captain George Norris (vessel Sprightly) as early as 1825. He gave the coordinates as 53°56'S, 5°30'E. This site can be found on the southernmost part of the Mid-Atlantic Ridge, southwest of the Cape of Good Hope, between the Cape Basin and the Atlantic-Indian-Arctic Basin in a part of the Southern Atlantic south of the northern limit of permanent sea ice. According to Baker (1967) this land might have been destroyed as a result of either a caldera

subsidence or an explosive eruption. The sketch, made by Norris, showed an island that has a gently domed form and a single sharp peak. A small hill on the island appeared to be a volcanic cone.

Many decades later, in 1893, Thompson Island was seen again, in this instance by Captain Joseph Fuller (vessel Francis Allyn) and was located "northeast of Bouvet" (Bouvetoya). The distance between these two islands might have been about 72 km. The German Deep Sea Expedition in the year of 1898 was unable to find Thompson Island. Therefore it is generally assumed that the island in question disappeared between 1893 and 1898.

Lamb (1967, 1970, 1971) is of the opinion that a very powerful, Krakatau-like explosive eruption provides the most reasonable explanation for the disappearance of this island. On the basis of climatological data he has put the date of the eruption as either 1895 or 1896. Also according to his opinion, the original island might have had a conical shape with a radius of 1 (or 2?) km at sea level (Baker has mentioned that from Norris' sketch map it appears to have been a very small island measuring 1 km by 2 km). Lamb supposed, furthermore, that the peak was about 0.5 km high and had a base about 1.5 km below sea level. His calculations gave 35 km^3 for the quantity of material dispersed during the catastrophe, and one-tenth to one-fifth of this could have been dispersed in the form of fine dust. Note that the generally accepted value for the dispersed total volume in the case of Krakatau in 1883 is only 18 km^3, and in the case of Tambora in 1815 is 30 km^3. (The latter value is from Neumann van Padang, personal communication, during the First International Scientific Congress on the Volcano of Thera, Athens, 1969). Accordingly, the explosion and the caldera-collapse process at Thompson Island that led to the complete destruction and disappearance of this land might have been really a particularly powerful one.

We fully accept the statement according to which large volcanic eruptions can influence the Earth's climate for 1-5 years or more, as this has been partly suggested by meteorological reasearch, carried out by Humphreys in 1940 and more recently by Budyko, Mitchell, Lamb, and other authors. On this basis it is perfectly true that using climatological data it is possible to deduce (unknown or unobserved) volcanic eruptions.

Concerning Thompson Island, there are two unsolved problems. First: if such a very great outbreak occurs in the open ocean, the event should be followed by one or more tsunami(s). Let us remember, for example, Tambora (1815), Krakatau (1883) or Ritter (1888), respectively (see items 92, 218, and 234). Nevertheless, we have no data on seismic sea waves associated with the Thompson-event. The reason for the lack of tsunami data may be threefold.

a) This part of the Southern Atlantic, as mentioned above, is south of the northern limit of permanent sea ice (see the map of Atlantic Ocean, Atlas Plate 62, June 1968), compiled by the National Geographic Society of the USA). Hence, under such circumstances, a "normal" tsunami was not able to develop.

b) The respective, very remote part of the Southern Atlantic was not visited by ships too frequently in the last decade of the 19th Century, because of its very severe weather and the danger of drifting sea ice. Therefore, there were no witnesses of the events including the rather strange and unusual version of the tsunami, when the waves developed beneath and among very large ice-floes.

c) Buovetoya and Thompson Islands and vicinity are practically uninhabited. The distance between the site of Thompson Island and Gough Island is roughly 2000 km. The latter might have been an inhabited area (although surely not too densely populated) in the last decade of the 19th Century. Let us disregard now the presence and unknown effect of the sea ice, and let us suppose that the tsunami at its source was comparable to that of Krakatau. The height of the Thompson tsunami at its source is supposed thus to be 36 m. Plotting the observed heights against the distance between the source and the places of observations, we find that at a distance of 2000 km from Krakatau, the maximum height of the waves was only about 1.5 m. On this basis a similar value can be suggested for the Thompson tsunami at Gough Island. But normal sea waves with the same height are produced by a wind, the intensity of which on the Beaufort scale is 3 (the corresponding speed of the wind is 12-19 km per hour). On the Douglas Sea Scale this corresponds to 3 degrees, which means a wave height of 0.9-1.5 m. When it is supposed that the tsunami at its source was two times greater than that of Krakatau, the values at a distance of 2000 km wil be as follows: probably maximum tsunami height: 3 m; and such great normal sea waves are produced by winds the intensity of which is 7 or 8 degrees on Beaufort's scale (50-74 km per hour). On the Douglas Sea Scale these values correspond to 5 degrees, where the height of the sea waves varies from 2.4 m to 3.6 m. Considering now that Gouth Island is lying in the open ocean where such winds, having 7 or 8 degrees intensity on the Beaufort scale are very frequent phenomena, we can state that the waves due to the Thompson tsunami, were not discernible from the frequent, normal waves of the water that are due to winds, particularly at the time of storms.

The second unsolved problem regarding Thompson Island is the fact that the soundings, carried out by the South African Navy, in the region 72 km northeast of Bouvetoya, did not reveal any submarine features, such as a shoal or a seamount at the former site of the alleged island (Baker, 1967). At the point in question a depth of 1645 m was established.

The lack of traces -- again in our opinion -- can be understood if one takes into consideration the tectonic position of the island, for the site of which we accept the coordinates given by Captain Norris.

Figure 253/1 shows the 2000-fathom depth-contour, the submarine base of Buovetoya, the location of Thompson Island, and the northern limit of sea ice. Using the chart of deep-oceanic relief (Atlantic Ocean Floor, 1968, published by the National Geographic Society of USA) it can be stated that Thompson Island was located exactly at the edge of a transform fault (see TH and TR F in Fig. 253/2). If the soundings were made only a few kilometers east of the real site of the island in question, it is quite clear that the result was a great depth. And, at the same time, it is evident that no shoal or seamount could be found here, because if a strong eruption of the Krakatau-type had taken place in such a critical area, not only explosions had to occur but at the same time submarine slumps, rock- and mud-avalanches and slides also accompanied the event. By other words, submergence due to down-faulting was associated with the eruption. At the time of paroxysm, the island, as a

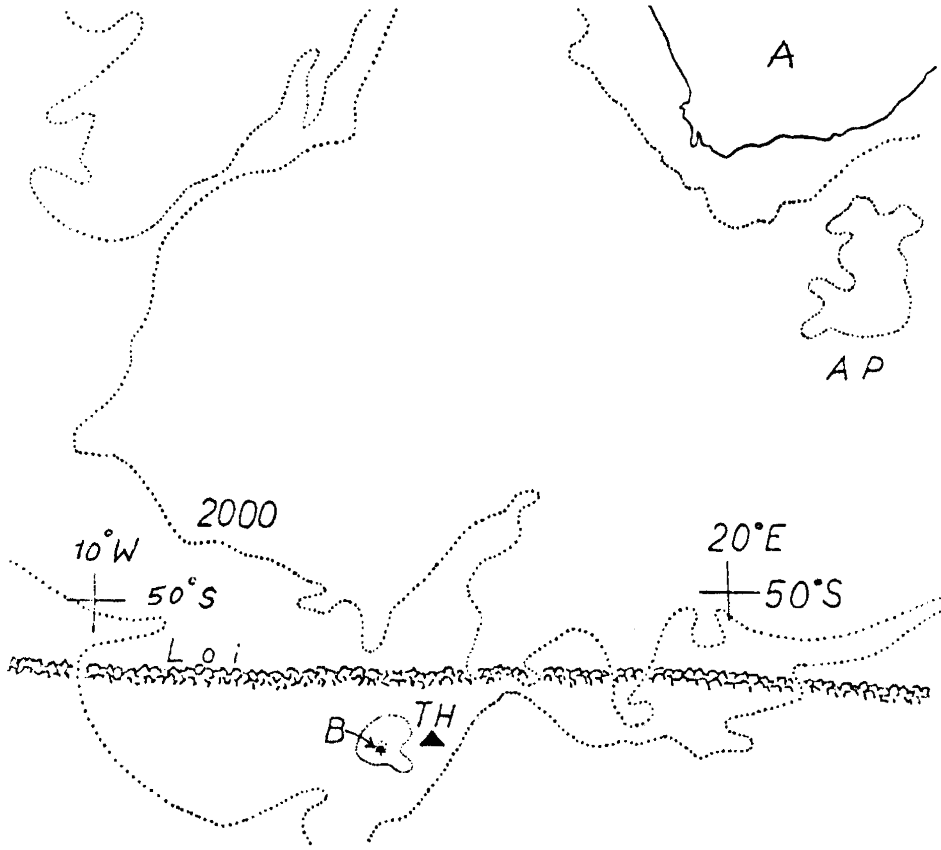
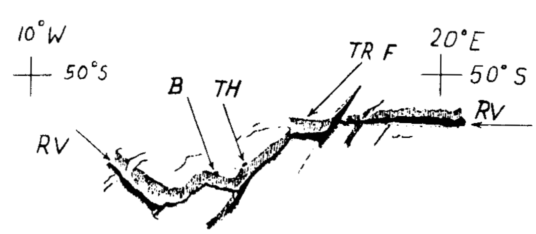


Figure 253/1.-- The position of Bouvetoya (B) and the site of Thompson Island (TH). A: Africa; AP: Agulhas Plateau; Loi: limit of ice. Labelled lines are depth contours in fathoms. The submarine base of Buovetoya is also shown.

Figure 253/2.-- Tectonic setting of Thompson Island (TH). Symbols used: A: Africa; RV: Rift Valley; B: Bouvetoya; TR F: transform fault. Only the near environs of Thompson Island are indicated, on the basis of a recent map of submarine features in the southern Atlantic. Vertical relief is strongly exaggerated.



whole, submerged suddenly and its dispersing material, including both the subaerial part and the submarine base alike, slid or collapsed into the depth, represented by the transform fault in question. The Thompson Island was literally swallowed by the ocean.

Our concluding remarks are as follows:

1. As the Bouvetoya Island has lavas that are rather siliceous in character (Baker 1967), we can suppose that its sister-island, Thompson, at a distance of only 72 km, might have had a similarly siliceous lava. Therefore an eruption of the Krakatau type, characterized by extraordinarily powerful explosions, seems to be quite probable and possible in the case of Thompson Island.

2. The tsunami that accompanied the explosions and the sudden submergence of the island was not observed, because (1) no ships were near the site of the event and therefore there were no witnesses; (2) no ships were nearby due to the presence of very large ice floes (or a permanent covering of ice) in the vicinity of Thompson Island, and the tsunami had a peculiar and perfectly unusual character, very different from that of the "normal" ones; (3) the nearest (probably) inhabited island (Gough) lies some 2000 km from Thompson Island, and at such a great distance the tsunami waves (if they could form at all among the floating ice floes)--having a height of 1 or 2 m or else 3 m at the utmost--were not discernible from the normal waves of the water due to winds and storms, respectively.

3. On, or very near, the site of the former island a rather great depth can now be measured, amounting to 1645 m, but no shoals or seamounts have been discovered. This is explained by the supposition that the island as a whole slid or collapsed into the depth represented by the neighbouring transform fault. Considering and accepting the coordinates given by Captain Norris, we can state that the island had been situated just at the edge of the western wall of this feature. At the time of the paroxysm a great deal of material from the island was dispersed and disintegrated, partly as a consequence of the explosions and partly as a result of the sliding or collapsing displacement toward the depth.

4. The former existence of the island in question is known without any doubt, not only because it was seen at two different times by the crew of two different ships, but, in addition, because the climatic anomaly of the southern hemisphere in the last decade of the nineteenth cenury can be explained by the direct effect of a particularly powerful eruption in the southern hemisphere (Lamb 1967, 1970, 1971).

↑ ★↴ ≌ ?

254. 1896 September -- Unnamed submarine volcano, Iceland

Probable location of the event: 63°20'N (?), 20°15'W (?). Submarine eruption reportedly accompanied earthquake in southern Iceland. Report of doubtful reliability (Berninghausen 1964).

⊼ ?

255. 1896 -- Bayonnaise Rocks, Izu-Mariana Islands

Submarine activity 14 km north of Bayonnaise Rocks. Approximate location of the Rocks: 31°55'N, 139°55'E. The outburst produced a reef projecting above sea level (Kuno 1962).

⊼ ★

256. 1897 September 21 -- Jolo, Sulu Archipelago

is supposed (Neumann van Padang 1953). Although Iida et al. (1972) gave no information about the submarine activity, they discussed the tsunami as follows. Its generating area was the Sulu Sea or the Celebes Sea near the Sulu Islands. The magnitude is assigned as 1?; the maximum height reached by the waves was 6 m at Solo, Sulu Islands. It was the greatest tsunami in the histoiry of the Philippine Islands. Two strong waves were observed. About 25 buildings were demolished and some people lost their lives.

Jolo volcano itself is characterized by Neumann van Padang (1953) to be either an island or a submarine volcano. The island is located at 5° 55' N, 121° 10' E, and is almost entirely blanketed with volcanic materials. An eruption 1641 January 4, is mentioned by the Catalogue of Active Volcanoes of the World, but its submarine or subaerial character is not stated.

⊼ ? ≌

257. 1897-1901 -- Karua, New Hebrides Islands

An eruption-cycle commenced in 1897. At the end of the cycle a new island emerged from the sea in 1901, having had a length of 1 km and a height of 15 m. After half a year it gradually disappeared (Fisher 1957).

⊼ ★★↴

258. 1898 -- Falcon Island, Tonga Volcanic Group

The new island that came into being in 1885 (see item 224) disappeared. In this year only a shoal remained, about 90 m in extent (Richard 1962).

★↴

259. 1899 September 8 -- Ruang, Sangihe Islands

Likely a printed error in Heck's paper (1947). Correct version: see item 236.

?

C. SUPPLEMENTS AND A LIST OF EVENTS OF UNKNOWN DATE AND/OR UNKNOWN LOCATION

260. 215 B.C. -- Vulcano Lipari Islands

Submarine activity (Sapper 1927). Not sure.

⊼ ?

261. 126 B.C. -- Vulcano, Lipari Islands

Submarine activity near Vulcano (Sapper 1927). Doubtful.

⊼ ?

262. 708 A.D. -- Sakura-zima, Kyushu

Submarine eruption, new island? (Sapper 1927).

⊼ ★ ?

263. 764 December -- Kamuzukuri (Kamizukurishima), Kyusyu

Near Sakura-zima a submarine eruption took place that was followed by the birth of a small group of islands. The activity commenced probably in December 764 and lasted a few years. Location of the eruption: 31°40'N, 130°43'E (Neumann van Padang 1938).

⊼ ★

264. 872 -- O-sima, Izu-Mariana Islands

Accompanied by rumblings, a new island came into being near O-sima (Sapper 1927). Doubtful; it is not mentioned in the Catalogue of Active Volcanoes of the World (Kuno 1962).

⊼ ★ ?

265. 1050 -- Santorini, Aegean Sea. Supplement to item 16

According to Ambraseys (1962), the date is most probably erroneous; 1650 is the probable date.

S

266. 1185-1190 -- Sakura-zima, Kyushu

Sapper (1927) has mentioned two new islands. Doubtful, not mentioned by Kuno (1962).

⊼ ★ ?

267. 1211 -- Eldey, Iceland

Submarine eruption on the Reykjanes Ridge, coinciding with great earthquakes. A new island came into existence--Eldeyjar, Island of Fire--while the old islands disappeared from the spot where they had always been. This indicates that there was volcanic activity in the area long before 1211 (Thorarinsson 1965). Sapper (1927) also mentioned this eruption and a new island at 63°45'N, 23°W. The event is briefly discussed by Neumann van Padang (1938) as well.

★↓ ⊼ ★

268. 1332 -- Unnamed submarine volcano, Iceland. Supplement to item 21

From a contemporary annal: "...from the Fljat and from many other districts in the North of Iceland a new island was seen to have emerged to the northwest of Grimsey." (Thorarinsson 1965).

S ⊼ ★

269. 1340 (about this year) -- Eldey (the near environs of Iceland)

Southwest of Reykjanes (near or in the place of Eldey), possibly submarine eruption (Thorarinsson 1965).

⊼ ?

270. 1456 -- Unnamed submarine volcano, Iceland. Supplement to item 25

According to Thorarinsson (1965, p. 74) "Jan Mayen may possibly be the island referred to."

S

271. 1476 October 9 -- Sakura-zima, Kyushu

Eruption from a parasitic crater, explosions and lava flows (Kuno 1962). Some old Japanese sources have mentioned a simultaneous submarine outbreak, accompanied by the birth of a new island as well as seismic sea waves. The submarine activity and their consequences are, however, doubtful.

∞ ↑ ⇝ ⊼ ? ★ ? ≃ ?

272. 1541 September 10 -- Agua, Guatemala

A rather strange event - namely a "water-eruption" - is mentioned by Sapper (1927). According to his opinion, however, the phenomenon might have been a lahar. Another possibility is the draining of the crater lake (Mooser et al. 1958). Except for this case, lahars are not treated in the present catalog.

⌒↗ ?

273. 1605. Nameless submarine eruptive point, Southern Atlantic

Sapper (1927) has mentioned an eruption "far from (*Fernando de*) *Noronha* at 7°S and 3°"--but neither west nor east is indicated for the second coordinate. It must be emphasized that along the 7°S latitude neither 3°W, nor 3°E is a volcanic region, although the point at 7°S, 3° E can be found in the continuation of the Cameron-Sao Tome volcanic chain. The event is regarded as very doubtful. No further data are available in other sources.

⊼ ? ?

274. 1613 -- Unnamed submarine volcano, Iceland

"On Bishop Thorlaksson's map of the North Atlantic of 1669 there is an island located quite a long way to the southwest of Iceland and this island is said to have been seen by Spanish sailors in 1613. We have no other knowledge of this island. It may have been on the Reykjanes ridge." (Thorarinsson 1965, p. 74.)

⊼ ? ★ ?

275. 1755 November 18 -- Nameless submarine eruptive center, Northern Atlantic

Sapper (1927) has explained that the eruption in question is very doubtful. We share his view, considering that the point at 42°38'N, 65°57'W is lying south of Nova Scotia, which is not a volcanic region at all.

⊼ ? ?

276. 1755 -- Nameless submarine volcano, Iceland

In this year there seems to have been an eruption somewhere north of Iceland, but the position is unknown and it may possibly have been Jan Mayen (Thorarinsson 1965).

⊼ ?

277. 1781 April 11 -- Sakura-zima, Kyushu.

Supplement to item 71

A new island came into being (Sapper 1927). Not mentioned elsewhere, therefore doubted.

S ⊼ ★ ?

278. 1782 -- Sakura-zima, Kyushu

Submarine activity, no further data (Sapper 1927). Doubtful.

⊼ ?

279. 1783 May 3 -- Eldey, Iceland. Supplement to item 73

The new island (Noyoe, Nyey, or Nyoe) was first observed and sketched on May 3 by Captain Mindelberg and crew of the Danish brig "Boesand." The island reached a diameter of at least 900 m. "The Danish Government showed a great interest in this island which received the name Nyey (Nyoe) = New Island. A royal decree was issued to the effect that an expedition should be sent to the island to hoist the Danish flag and set up a 3 ells high stone inscribed with the royal insignia. The stone never found its way to the island simply because the island could not be found in the autumn of 1793." (Thorarinsson 1965, p. 74.)

S ⊼ ★

280. 1806 -- Unnamed undersea volcano, Equatorial Atlantic

According to Sapper (1927), a submarine eruption took place at 2°43'S, 22°55'W. Doubtful, as it is not mentioned by other authors.

⊼ ?

281. 1814 -- Nameless submarine eruptive point, Kamchatka

A submarine eruption is mentioned, without any further details, by Russel (1888). Uncertain.

⊼ ?

282. 1815 April 5-12 -- Tambora, Lesser Sunda Islands. Supplement to item 92

Neumann van Padang (1971) has discussed some important further facts concerning the great eruption of Tambora in 1815. As the direct result of the outburst, 10,000 persons lost their lives on Sumbawa and the neighboring islands. Due to epidemics and famine, as indirect effects of the eruption, a further 38,000 people died on Sumbawa and 44,000 on Lombok. Considering these data, the Tambora-eruption is regarded to be the most destructive outburst during the present millennium.

Although the Tambora eruption was greater in intensity than that of Krakatau in 1883, its tsunami was much less powerful. This fact can be explained by considering that the collapse of the mount happened largely well above the sea level, and not partly below the sea level as in the cases of Krakatau and of Santorini, where the newly formed caldera was inundated immediately by the water. The height of the tsunami on April 10 at the coast of Sumbawa was 4 m, at any rate much smaller than the height of the tsunami at Java and Sumatra, on opposite sides of Sunda Strait after the paroxysm of Krakatau. At a distance of 85 km from Tambora, at Bima, the tsunami was strong enough to tear ships off their chains and after this the water run among the houses along the port. At

Besuki, lying at a distance of 450 km from Tambora, the height of the wave was 180 cm.

S ↑ ≌

283. 1827 -- Unnamed submarine volcano, Azores

East of the islands floating pumice was found (Sapper 1927). Although it is not mentioned by other sources and the location is unknown, the event is an accepted one.

⊼

284. 1831 August -- Nameless submarine volcano, Lesser Antilles

Near Barbados a submarine eruption might have happened. Ash fall was observed in 20 villages on the Lesser Antilles (Sapper 1927). Note: On 11 August 1831, at night, five or six shocks were felt at Martinique, but only one was strong (Robson 1964). Maybe these shocks were associated with the submarine activity that is accepted as valid.

⊼

285. 1836 -- Nameless submarine volcano, Equatorial Atlantic. Supplement to item 117

For the year 1836 two submarine eruptions are reported (Sapper 1927), but no further data are given. The locations were as follows:

1°35'S, 20°45'W, and 0°35'S, 15°50'W,

respectively. The second was mentioned in item 117 as the site where black ash of volcanic origin has been collected, but the unnamed submarine volcano that erupted on 1836 January 25 is located at 0°40'S, 20°10'W. Although there are certain differences among the coordinates, it can be supposed that the submarine volcano at 0°40'S, 20°10'W may be identical with one of the two volcanos that are mentioned by Sapper.

S ⊼

286. 1837 November 25 -- Unnamed undersea volcanic center, Bahama Bank

A remarkable light-phenomenon was seen, but its volcanic nature is doubtful (Sapper 1927). Note: Although no exact location is given, no volcanic manifestation can be supposed if one considers that the Bahama Bank is not a volcanic region. The event is not mentioned in other sources; therefore, we share Sapper's opinion about the uncertainty of the phenomenon. As an interesting coincidence of events it is worth mentioning that 5 days later a severe earthquake was observed on Martinique (Robson 1964). We are sure, however, that this shock had nothing to do with the light-phenomenon. The distance between the Bahama Bank and Martinique is too great.

⊼ ? ?

287. 1839 -- Unnamed undersea volcano, Northern Atlantic

A submarine eruption is reported by Sapper (1927) at 31°42'N, 42°30'W. As no further details are given and the event is not mentioned by other authors, the eruption is regarded to be doubtful.

⊼ ?

288. 1844 -- Nameless submarine volcano, Azores

Rhythmic murmur was heard. No exact location is given (Sapper 1927). The volcanic nature of the event is very doubtful.

⊼ ? ?

289. 1845 February 8 -- Soputan, Celebes.

Normal explosions from the central crater took place. A tectonic earthquake occurred and a tsunami with a magnitude of 0 (?) was observed at Manado (Lida et al., 1972). The tsunami was due to this shock. Only an indirect relation with the eruption can be supposed.

⊼ ?

290. 1852 -- Submarine eruptive center, Equatorial Atlantic

Undersea activity is mentioned by Sapper (1927) at 0°12' N (?), 19° W. No further data are available; uncertain.

Note: In what follows events will be summarized for which the date of occurrence is unknown. Therefore it may be that some of the phenomena took place after 1900 January 1. Other events that occurred after this date will be treated in the second volume.

⊼ ?

291. ...?... Submarine eruptive center, Kurile Islands

The event perhaps took place in the 1880s. Although the year is unknown, Sapper (1927) gave the month and day as July 12. Rumblings every 15 minutes. The volcanic nature of the phenomenon is uncertain.

⊼ ?

292. ...?... Submarine eruption point, Juan Fernandez Islands

Location (Sapper 1927): 33°20'N, 78°20'W. Questionable. The latitude is erroneous; 33°20'S should be read instead of 33°20'N.

⊼ ?

293. ..?... Underwater eruptive center, Tonga Volcanic Group

More than one submarine eruption was reported "not too far from Late" or Lette (Sapper 1927), near the Home Shoal Deep at 19°17'S, 174°45'W. Uncertain.

⊼ ?

294. ...?... Yersey, Lesser Sunda Islands

The date of its eruption is unknown; the esistence of the submarine volcano is doubted (see item 245).

⊼ ?

295. ...?... Submarine eruptive center, Gulf of Aden

A submarine volcano is mentioned at 12°15'N, 45°00'E, but it is regarded as problematical by Neumann van Padang (1963).

⊼ ? ⊼̸ ?

296. ...?... Ormus Islands, Gulf of Oman

The Ormus Islands in the Gulf of Oman, between the Persian Gulf and the Arabian Sea, are of volcanic origin. These islands still have well-shaped craters and lava flows. Sapper mentioned lava effusions in the Strait of Oman that must have had taken place in the Middle Ages (in the historical, not in the geological meaning). All these data give the impression that volcanic activity has not yet fully died in this region (Neumann van Padang 1963). Accepting this possibility, only the submarine nature of the activity is questioned.

⊼ ? ?

297. ...?... Nameless submarine volcano, Southern Atlantic

An underwater outbreak was reported at 15°30'S, 21°45'W. The event is very doubtful because at this point the depth of the Atlantic Ocean is 5300 m (Neumann van Padang 1963), and thus it can hardly be imagined that the activity--if any--would have been observed on the surface. Incidently, the place mentioned is far west of the rift valley of the Mid--Atlantic Ridge.

⊼ ? ?

298. ...?... Nameless submarine volcano, Southern Atlantic

The eruption was reported at 12°45'S, 21°45'W. This event is also very doubtful, similar to item 296, as the depth of the ocean here is 5300 m (Neumann van Padang 1963).

⊼ ?

299. ...?... Nameless submarine volcano, Southern Atlantic

The submarine outbreak at 30°50'S, 30°48'W has not been proven, therefore it is problematical (Neumann van Padang 1963).

⊼ ?

300 ...?... Unnamed submarine eruption center, Bonin Islands

Sapper (1927) has mentioned an outburst at 25°20'N, 141°20'E. Questionable.

⊼ ?

301. ...?... Unnamed submarine volcano, Luzon Strait, Philippine Islands

In Sapper's book (1927) a submarine outbreak is mentioned at 20°20'N, 121°45'E in the Luzon Strait, northwest of Babuyan Islands. No further data are available; the event is regarded as doubtful.

⊼ ?

302. ...?... Nameless submarine eruption site, Flores Sea

Sapper (1927) has mentioned an eruption at the point located at 7°30'S, 119°30'E. The event is problematical and an eruption far north of the Indonesian volcanic belt is unlikely.

⊼ ?

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LIST OF SUBMARINE VOLCANO LOCATIONS

Events marked * are associated with tsunamis

Name and serial number	Latitude ° '	Longitude ° '	Catalog Event Number
AGUA, Guatemala, 1402-10	14 28.0 N	90 44.5 W	272
AMBOINA, Moluccas	03 41 S	128 10 E	40*
ANTARCTICA, Scotia Arc, nameless submarine volcano near Tierra del Fuego, 19c 1900-027	56 15 S or 65 15 S	72 10 W	189
ARAKAN, Indian Ocean, submarine (mud) volcano, 0305	18 00 N	93 30 E	123
ASSONGSONG, Izu-Mariana Islands, 0804-15	19 40 N	145 24 E	96*
ATITLAN, Guatemala, 1402-06	14 35 N	91 11 W	113*
AUGUSTINE, Alaska (see St. Augustine, Alaska)			
AVACHINSKY, Kamchatka, 1000-10	53 13 N	159 00 E	54*, 101*
AWU, Sangihe Islands, 0607-04	03 40 N	125 30 E	136*, 244*
AZORES, Unnamed submarine volcanoes, 1802-8a	37 52 N	25 43 W	33, 41, 48, 86, 87
1802-3a	38 30 N	27 25 W	82
	39 57 N	25 50 W	146
	38 30 N	28 00 W	205
	?		59, 283, 288
BAHAMA BANK, Unnamed submarine volcano	?		286
BANDA API, Banda Sea, 0605-09	04 31 S	129 52 E	131*
BANK NNW OF PANTELLARIA, Sicily Sea (see Foerstner, Phlegraean Fields of the)			
BANUA WUHU, Sangihe Islands, 0607-03	03 08 N	125 29 E	116, 235*, 247, 251
BAYONNAISE ROCKS, Izu-Mariana Islands, nameless submarine volcanoes (see also Myojin Sho), 0804-07	31 55 N	139 55 E	179, 255
BISMARCK ARCHIPELAGO, unnamed submarine volcano near Narage, 0502-02	04 33 S	149 07 E	152
BOGOSLOF, Aleutian Islands, 1101-30	53 56 N	168 02 W	64, 81, 83, 85, 90, 97, 210 219, 220, 221, 233, 241
BONIN ISLANDS, unnamed submarine volcano, 0804-10	26 00 N	140 46 E	299
BRIMESTONE ISLAND, Kermadec Volcanic Group, 0402-02	30 13 S	178 55 W	100
CAMIGUIN DE BABUYANES, Islands north of Luzon, Philippines, 0704-01	18 55 N	121 52 E	144
CAMPI FLEGREI DEL MAR DI SICILIA (see also names of individual volcanoes), 0101-07	37 06 N	12 42 E	3, 32, 43, 104, 105, 106, 107, 108, 109, 110, 111, 112, 124, 153, 207, 242, 243
CAPE COLUMBO (Santorini), Aegean Sea	36 24 N (approximate)	25 23 E	35*
CAPE OF GOOD HOPE, unnamed submarine volcano nearby	uncertain		143
CARABALLOS, north of Luzon, Philippines,	uncertain		31*

LIST OF SUBMARINE VOLCANO LOCATIONS (Continued)

Events marked * are associated with tsunamis

Name and serial number	Latitude ° '	Longitude ° '	Catalog Event Number
CENTRAL MEDITERRANEAN SEA, nameless submarine eruptive centers	uncertain		227, 228*
CHINA SEA, unnamed submarine volcano, 0801-04	25 25 N	122 20 E	168
CORCOVADO, Chile, 1508-05	43 11 S	72 48 W	114*
CRATER LAKE, Oregon, 1202-16	42 56 N	122 07 W	15
DIDICAS ROCKS, Islands north of Luzon, Philippines, 0704-02	19 04 N	122 10 E	66, 139
DON JOAO DE CASTRO BANK, Azores, 1802-07	38 13 N	26 37 W	52
ELDEY, Iceland, unnamed submarine volcanoes (see also Iceland and vicinity, 1701-02	63 45 N	22 55 W	17, 18, 19, 20, 24, 28, 73, 103, 202, 223, 267, 269, 279
EMPEROR OF CHINA, Banda Sea, 0605-01	06 37 S	124 13 E	245
EQUATORIAL ATLANTIC, unnamed submarine volcano, 1805-01, 02, 03, 04	see text for locations		62, 94, 99, 117, 129, 149 197, 280, 285, 289
FALCON ISLAND,Tonga Volcanic Group, 0403-05	20 19 S	175 25 W	72, 155, 194, 224, 232, 239, 246, 249, 252, 258
FLORES SEA, nameless submarine eruption site	07 30 S	119 30 E	301
FOERSTNER, Phlegraean Fields of the Sicily Sea, 0101-07a	36 48 N	11 54 E	242
FONUA FO'OU, Tonga Volcanic Group (see Falcon Island)			
FUJI-YAMA, Honsyu, 0803-03	35 21 N	138 43 E	46*
GAMKONORA, Halmahara, 0608-04	01 22 N	127 31 E	38*
GEORGIANA, Indian Ocean (see also Indian Ocean or Ninety East Ridge)	06 05 S	89 10 E	204, 212, 213, 214, 215, 216, 217
GIULIA FERDINANDEO BANK, Phlegraean Fields of the Sicily Sea (often called Graham Island), 0101-07b	37 12 N	12 42 E	32, 43, 104, 105, 106, 107, 108, 109, 110, 111 112, 153
GRAHAM ISLAND, Phlegraean Fields of the Sicily Sea (see Giulia Ferdinandeo Bank)			
GULF OF ADEN, submarine eruptive center, 0302-12	12 15 N	45 00 E	294
HATIZYO-ZIMA NISI-YAMA, Izu-Mariana Islands, 0804-05	33 07 N	139 46 E	30*
HEKLA, Iceland, 1702-07	63 58 N	19 42 W	42*
HOME REEF, Tonga Volcanic Group, 0403-08	18 59 S	174 46 W	132, 145
IBUGOS, Islands north of Luzon, Philippines, submarine volcanoes to the west, 0704-05	20 19 N	121 45 E	65, 127
ICELAND, unnamed submarine volcanoes (see also Eldey), 1703-18	67 07 N	18 36 W	21, 22, 25, 74, 75, 119 167, 254, 268, 274, 276

LIST OF SUBMARINE VOLCANO LOCATIONS (continued)

Events marked * are associated with tsunamis

Name and serial number	Latitude ° '	Longitude ° '	Catalog Event Number
INDIAN OCEAN, possible submarine volcano (see also Georgiana)	06 05 S	89 10 E	204, 212, 213, 214, 215, 216, 217
JOLO, Sulu Archipelago, 0700-01	05 55 N	121 10 E	256*
JUAN FERNANDEZ Islands, submarine volcanoes, 1506-03 and two others at 34° 55'S, 77° 38'W and 33° 20'S, 78° 20'W, respectively	33 37 S	78 47 W	115*, 166, 291
KAMCHATKA, nameless submarine eruptive points, 1000-36	57 25 N uncertain	160 24 E	88, 281
KAMUZUKURI, Kyusyu	31 40 N	130 43 E	263
KARUA, New Hebrides Islands, 0507-07	16 49 S	168 32 E	257
KERMADEC VOLCANIC GROUP, unnamed volcano, 0402-04	29 11 S	177 52 W	225
KILAUEA, Hawaii, 1302-01	19 25 N	155 16 W	77, 98, 121, 170, 191*
KITA-IWO-ZIMA, Izu-Mariana Islands, submarine volcanoes near or to the northwest, 0804-11	25 25 N	141 13 E	26, 70, 237
KOMAGA-TAKE, Hokkaido, 0805-02	42 04 N	140 40 E	34*
KONA-COAST, Hawaii			88*
KONIUSHI, Aleutian Islands, 1101-14	52 13 N	175 07 W	60
KRAKATAU, SUNDA STRAIT, 0602-00	06 06 S	105 25 E	12*, 218*
KRAKATAU, SUNDA STRAIT, activity 1883/May 20 - Aug. 26, just before the great eruption, 0602-00	06 06 S	105 25 E	204
KURILE ISLANDS, submarine eruptive center	?		290
LAKE ILOPANGO, Islas Quemadas, El Salvador, 1403-06	13 40 N	89 03 W	203
LESSER ANTILLES, nameless submarine volcano,	?		284
LUZON STRAIT, Philippine Islands, unnamed submarine volcano, 0704-05	20 20 N	121 45 E	300
MADREPOE BANK, Phlegraean Fields of Sicily Sea, 0101-07d	36 42 N	13 42 E	124
MARIE GALANTE, West Indies, nearby submarine volcano, 1600-07	15 08 N	61 17 W	122
MAUNA LOA, Hawaii, 1302-02	19 28 N	155 36 W	148, 169, 183*, 190*, 230
MAURELLE ISLANDS, Tonga Volcanic Group, 0403-07	19 11 S	174 51 W	182
MELANESIA, nameless submarine volcano, 0507-09	18 45 S	169 11 E	208
MERAPI, Java, 0603-25	07 32 S	110 26 E	120*
METIS SHOAL, Tonga Volcanic Group (see Maurelle Island also) 0403-07	19 11 S	174 51 W	128, 147, 182, 188, 201, 229, 240, 250
MINCHINAMAVIDA, Chile, 1508-04	42 47 S	72 26 W	114*

LIST OF SUBMARINE VOLCANO LOCATIONS (continued)

Events marked * are associated with tsunamis

Name and serial number	Latitude ° '	Longitude ° '	Catalog Event Number
MOSCHYLOS, Aegean Sea		?	2*
MYOJIN SHO, Izu-Marian Islands (can be found under the name, Bayonnaise Rocks, also), 0804-07	31 55 N	139 55 E	179, 255
NEW ZEALAND VOLCANIC ZONE, submarine eruption	38 00 S	178 00 E	193
NIEUWERKERK, Banda Sea, 0605-02	06 39 S	124 43 E	245
NINETY EAST RIDGE, Indian Ocean (see also Indian Ocean, possible submarine volcano, and Georgiana)	06 05 S	89 10 E	204, 212, 213, 214, 215, 216, 217
NISHI-YAMA, Izu-Mariana Islands, 0804-05	33 08 N	139 46 E	47
NORTHERN ATLANTIC, unnamed submarine volcanoes, 1801-01, 02, 03, 04	See text for locations		141*, 154, 222, 231, 248*, 275, 287
NOYOE (NYEY, NYO, NYOE), Iceland, 1701-01	63 28 N	23 46 W	73, 279
OKINAWA-TORI-SHIMA (RYUKYU-TORISIMA), Ryukyu Islands, 0802-02	27 52 N	128 15 E	36*
ONNIMAH STRAIT, near Cape Ommanen, northeastern Pacific	56 01 N	134 04 W	142
ORMUS ISLANDS, Gulf of Oman, 0302-14	26 00 N	57 00 E	295
OSIMA-O-SIMA, Hokkaido, 0805-01	41 30 N	139 22 E	55*
O-SIMA, Izu-Mariana Islands and O-Sima vicinity, 0804-01	34 43 N	139 22 E	23, 44*, 50*, 141, 176, 264
OSORNO, Chile, 1508-01	41 06 S	72 30 W	114*
PEAK OF TERNATE, Halmahera (see Ternate Peak)			
PERU, coast between Coronal and Iquique			151
PERU, near the coast of San Lorenzo Island			150
PERU, coast at Pisagua			192
PHLEGRAEAN FIELDS of the Sicily Sea (see the individual volcanoes and Campi Flegri del Mar di Sicilia)			
PICO, Azores, 1802-02	38 28 N	28 24 W	51
PINNE MARINE BANK, Sicily Sea, 0101-07c	36 54 N	13 00 E	125
PONDICHERRY, north of Ceylon, submarine volcano in Indian Ocean, 0305-01	11 45 N	80 45 E	58
PRIBILOF ISLANDS, Bering Sea	56 41 N	169 07 W	93
RALUAN, New Britain, 0502-14	04 16 S	152 10 E	198*
RAOUL ISLAND, Kermadec Volcanic Group, 0402-03	29 16 S	177 55 W	89, 135, 174, 184, 195
RITTER ISLAND, off northeast coast of New Guinea, 0501-07	05 31 S	148 07 E	234*
RUANG, Sangihe Islands, 0607-01	02 16 N	125 25 E	178*, 236

LIST OF SUBMARINE VOLCANO LOCATIONS (continued)

Events marked * are associated with tsunamis

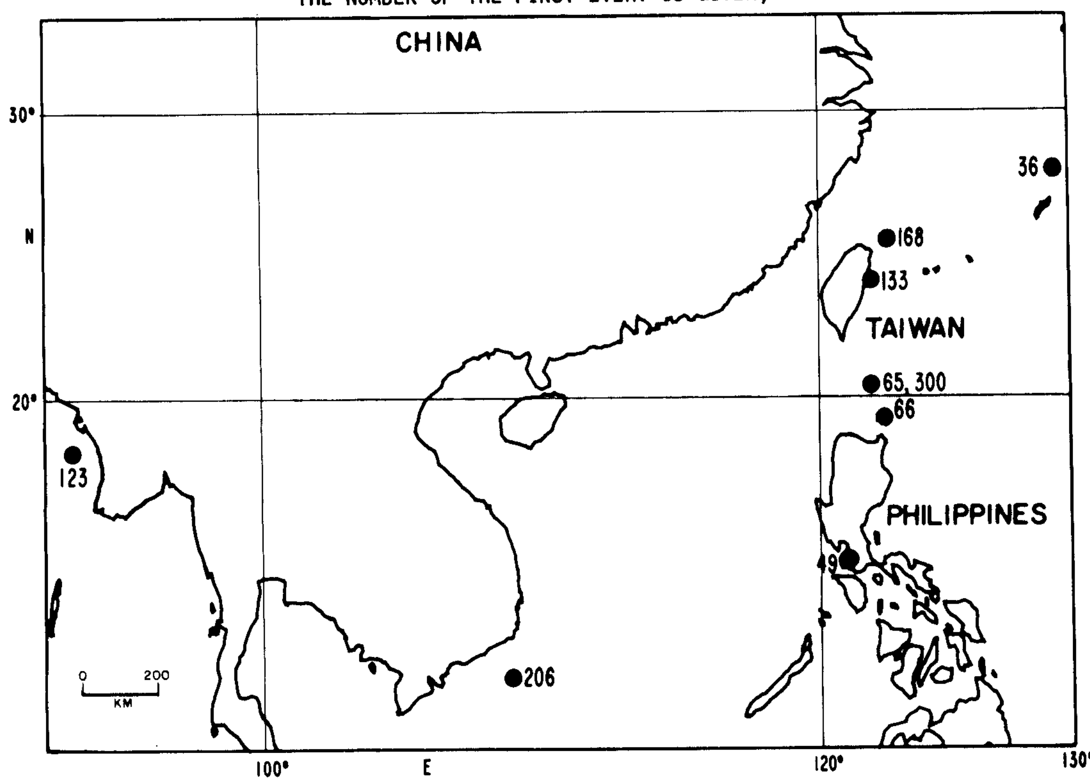
Name and serial number	Latitude ° '	Longitude ° '	Catalog Event Number
RYUKYU-TORISIMA, Ryukyu Islands (see Okinawa-Tori-shima)			
SABRINA, Azores, ephemeral island (see also Azores, unnamed submarine volcanoes), 1802-03	38 30 N	27 25 W	87
SAKURA-ZIMA, Kyushu, 0802-08	31 34 N	130 40 E	14*, 67*, 68*, 69*, 71*, 262, 266, 271*, 277, 278
SAMOA VOLCANIC GROUP, unnamed submarine volcano near Olosega Island, 0404-01	14 12 S	169 36 W	164
SANGIHE ISLANDS, nameless submarine volcano, 0607-05	03 58 N	124 13 E	245
SANTA BARBARA (Terceira), Azores, 1802-05	38 43 N	27 19 W	61, 165
SANTORINI, Aegean Sea, 0102-04	36 24 N	25 23 E	1*, 4, 5, 9, 10*, 13, 16*, 27, 35*, 45, 156*, 157, 158, 159, 160, 161, 162, 163, 175, 265
SAO JORGE, Azores, 1802-03	38 39 N	28 04 W	205, 209
SEMERU, Java, 0603-30	08 07 S	112 55 E	95*
SHUAM SHU (SHUAMSHU) ISLAND, Kurile volcanic belt	50 53 N	161 12 E	137
SICILY SEA (see names of individual volcanoes and Campi Flegrei del Mar di Sicilia)			
SLAMET, Java, 0603-18	07 14 S	109 12 E	187*
SMITH ROCK(S), nearby submarine volcanoes, Izu-Mariana Islands, 0804-08	31 16 N	139 46 E	37, 172, 173, 177, 181 185
SOUTHERN ATLANTIC, nameless submarine eruptive centers	see text for locations		130, 171, 273, 296, 297, 298
ST. AUGUSTINE, Alaska, 1103-01	59 22 N	153 25 W	76*, 220*
TAAL, Philippine Islands, 0703-07	14 00 N	121 00 E	49, 53, 56*, 57*
TAIWAN, nameless submarine volcano between Taiwan and the Mariana Islands, 0801	20 56 N	134 45 E	126
TAIWAN, submarine volcano near the eastern coast, 0801-3	24 00 N	121 50 E	133
TAMBORA, Lesser Sunda Islands, 0604-04	08 15 S	118 00 E	92*, 282*
TANNA, New Hebrides Islands, 0507-10	19 31 S	169 25 E	196*, 199*
TARAWERA, New Zealand, 0401-06	38 13 S	176 30 E	226
TAUPO VOLCANIC CENTRE, Central North Island, New Zealand, 0401-07	38 46 S	176 07 E	7
TERCEIRA, Azores (see Santa Barbara)			

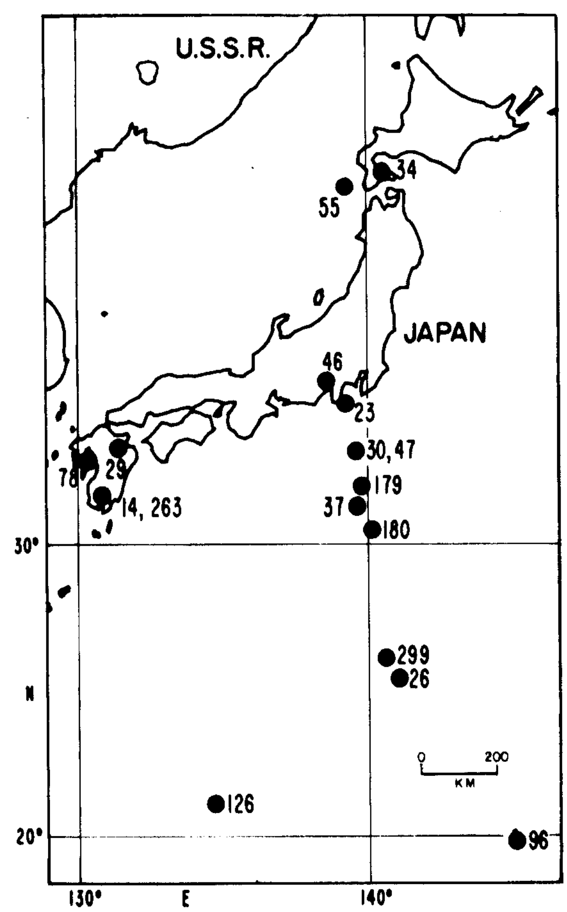
LIST OF SUBMARINE VOLCANO LOCATIONS (continued)

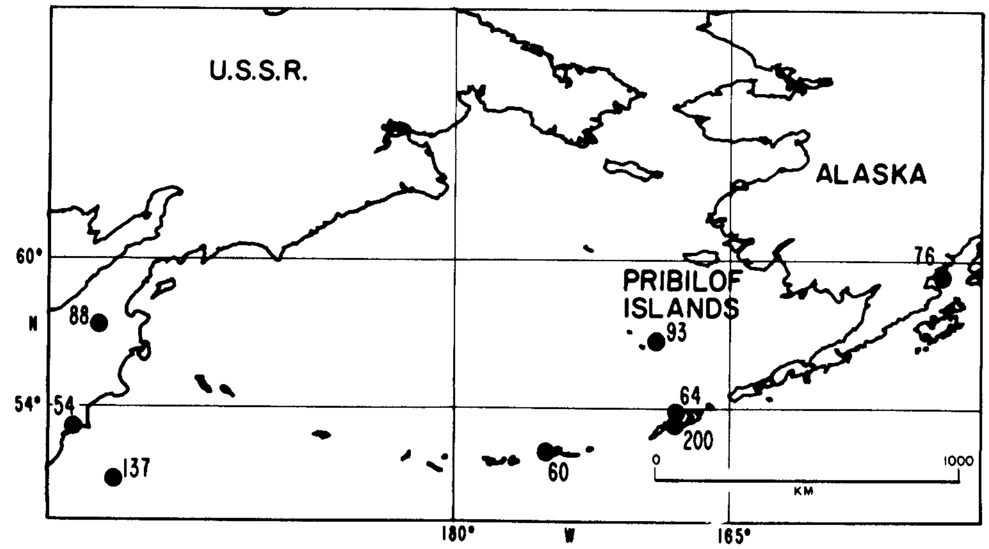
Events marked * are associated with tsunamis

Name and serial number	Latitude ° '	Longitude ° '	Catalog Event Number
TERNATE PEAK, Halmahera, 0608-06	00 48 N	127 19 E	39*, 63*
THOMPSON ISLAND, Southern Atlantic, 1806-03	53 56 S	05 30 E	253*
TONGA VOLCANIC GROUP, unnamed underwater volcanoes, 0403-05 (item 72; rest unnumbered)	See text for locations		72, 186, 238, 292
TORI-SIMA, Izu-Mariana Islands, nameless submarine volcano, 0804-09	30 28 N	140 14 E	180
TULISKOI (or TULIK), Aleutian Islands, 1101-29	53 25 N	168 08 W	200
TULUMAN, Admiralty Group, Melanesia, 0500-01	02 26 S	147 19 E	211
TURUMI, Kyusyu, 0802-13	33 16 N	131 25 E	29
UMNAK ISLAND, Aleutian Islands, nearby submarine volcano	?		84
UNALASKA ISLAND, Aleutian Islands, submarine volcano southeast and nearby	?		80, 91
UNIMAK ISLAND, Aleutian Islands, submarine volcanoes nearby	?		79*, 102*, 138*
UNZEN, Kyusyu, 0802-10	32 45 N	130 18 E	78*
VUSUVIUS, Italy, 0101-02	40 49 N	014 25 E	11*
VETERAN, Cochin China, 0705-01	09 49 N	109 03 E	206
VULCANELLO, Lipari Islands, 0101-05	38 24 N	14 57 E	6, 8
VULCANO, Lipari Islands, 0101-05	38 24 N	14 57 E	8, 260, 261
YERSEY, Lesser Sunda Islands, 0604-28	07 31 S	123 57 E	245, 293

MAPS OF EVENT LOCATIONS
(WHEN VOLCANO IS DISCUSSED IN MORE THAN ONE EVENT,
THE NUMBER OF THE FIRST EVENT IS GIVEN)



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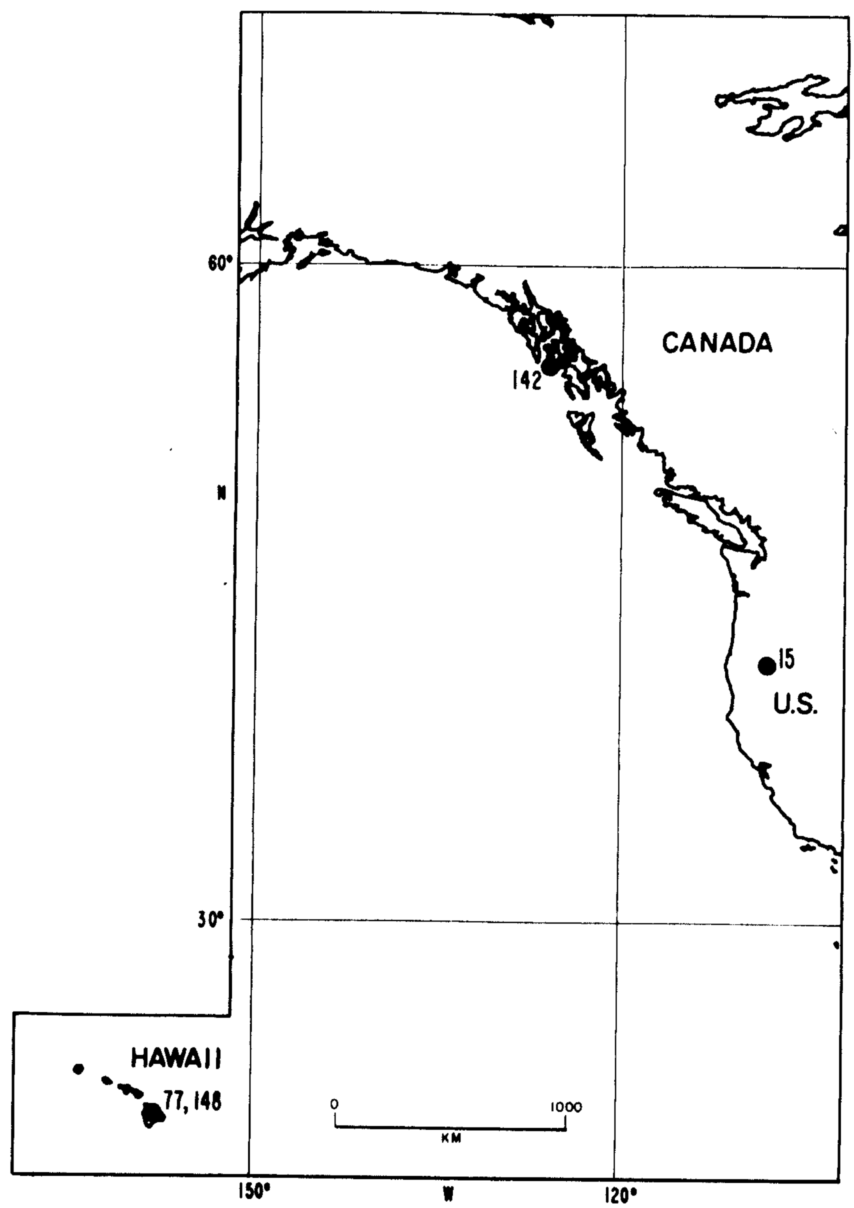
ALASKA
60°
PRIBILOF
ISLANDS
76
88
N
93
54°
54
64
200
137
60
0
1000
KM
180°
W
165°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CANADA
142
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HAWAII
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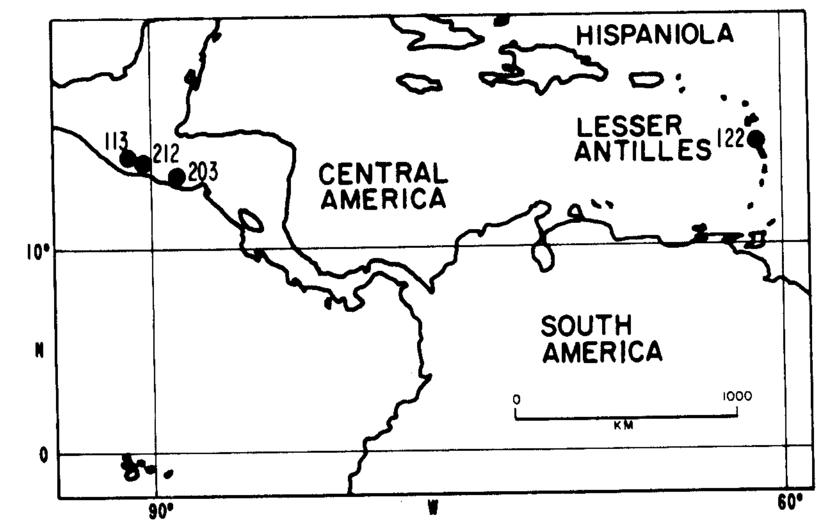
120°


HISPANIOLA
LESSER
ANTILLES
122
113
212
203
CENTRAL
AMERICA
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N
SOUTH
AMERICA
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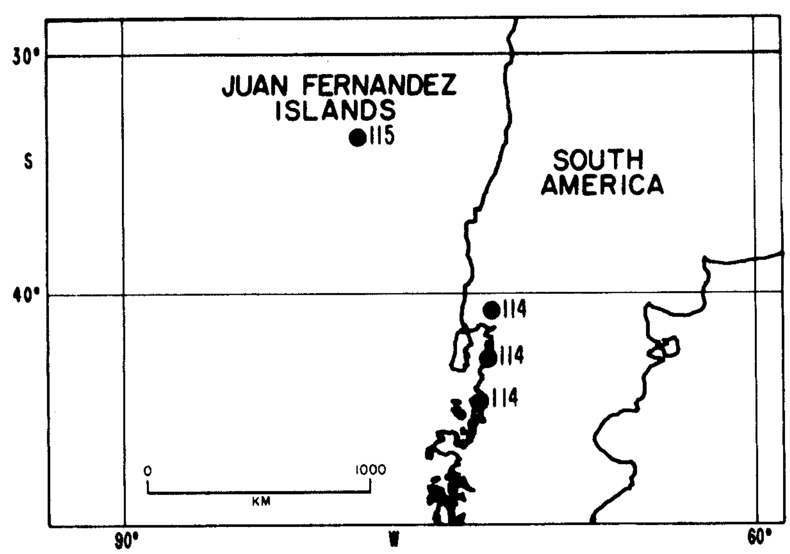
KM
0
90°
W
60°


30°
JUAN FERNANDEZ
ISLANDS
115
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SOUTH
AMERICA
40°
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114
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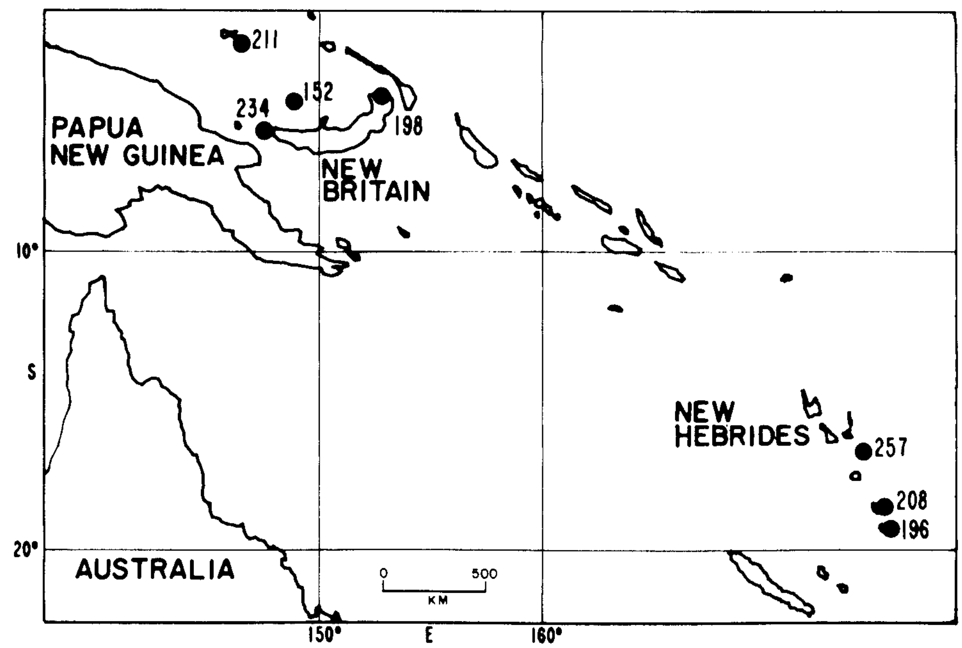
211
152
234
198
PAPUA
NEW GUINEA
NEW
BRITAIN
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S
NEW
HEBRIDES
257
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196
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AUSTRALIA
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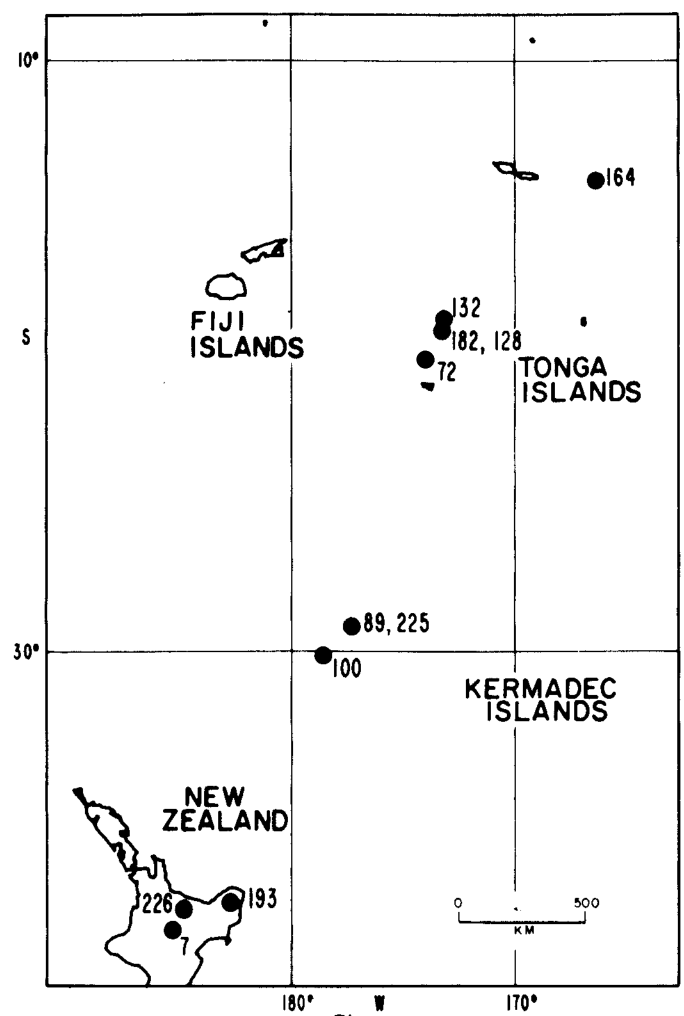
E
160°


10°
164
FIJI
ISLANDS
132
182, 128
72
TONGA
ISLANDS
S
89, 225
30°
100
KERMADEC
ISLANDS
NEW
ZEALAND
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193
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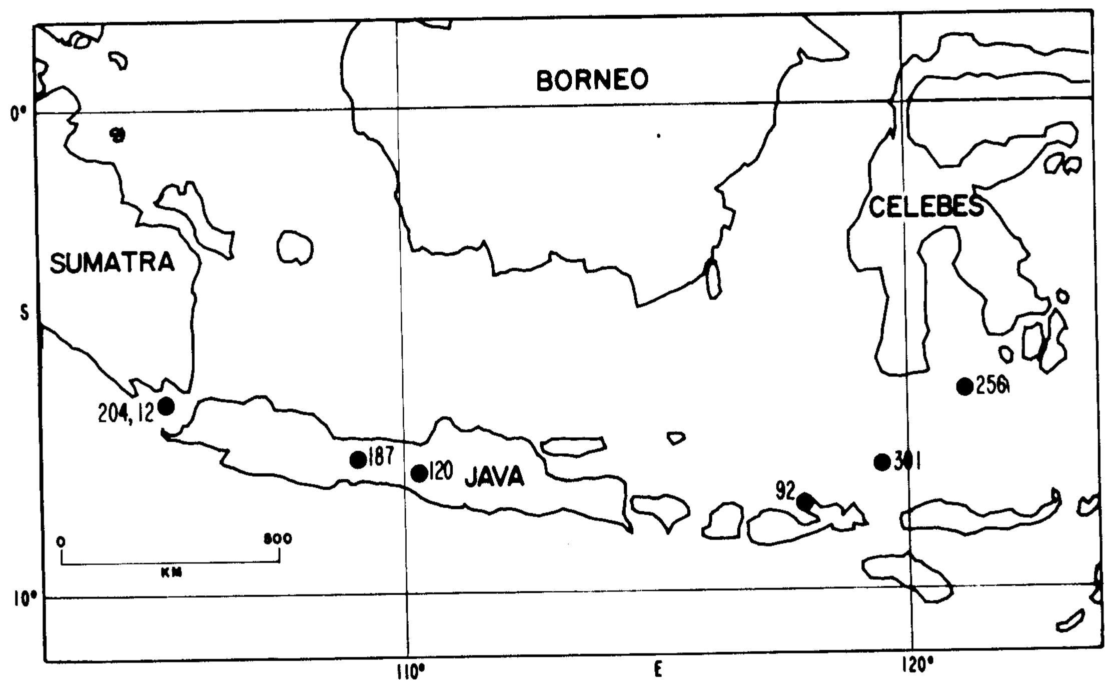
KM
180°
W
170°

B4


BORNEO
0°
CELEBES
SUMATRA
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JAVA
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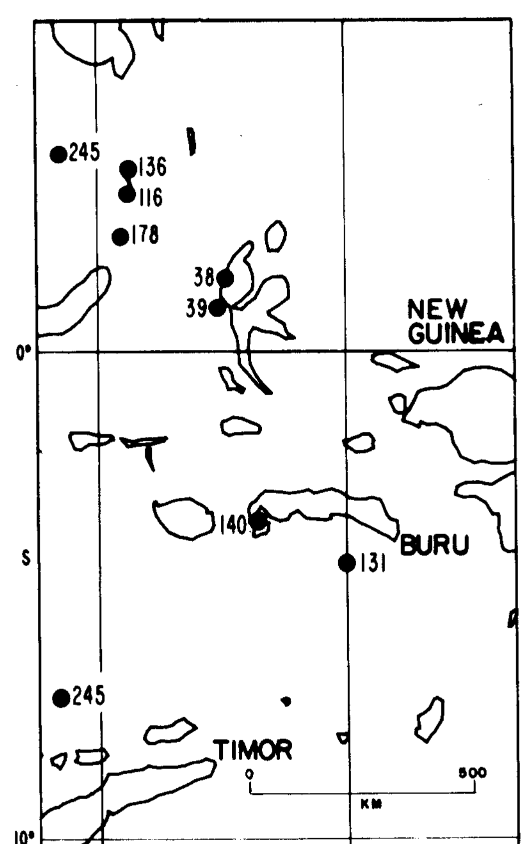
500
KM
10°
110°
E
120°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136
116
178
38
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NEW
GUINEA
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BURU
S
131
245
TIMOR
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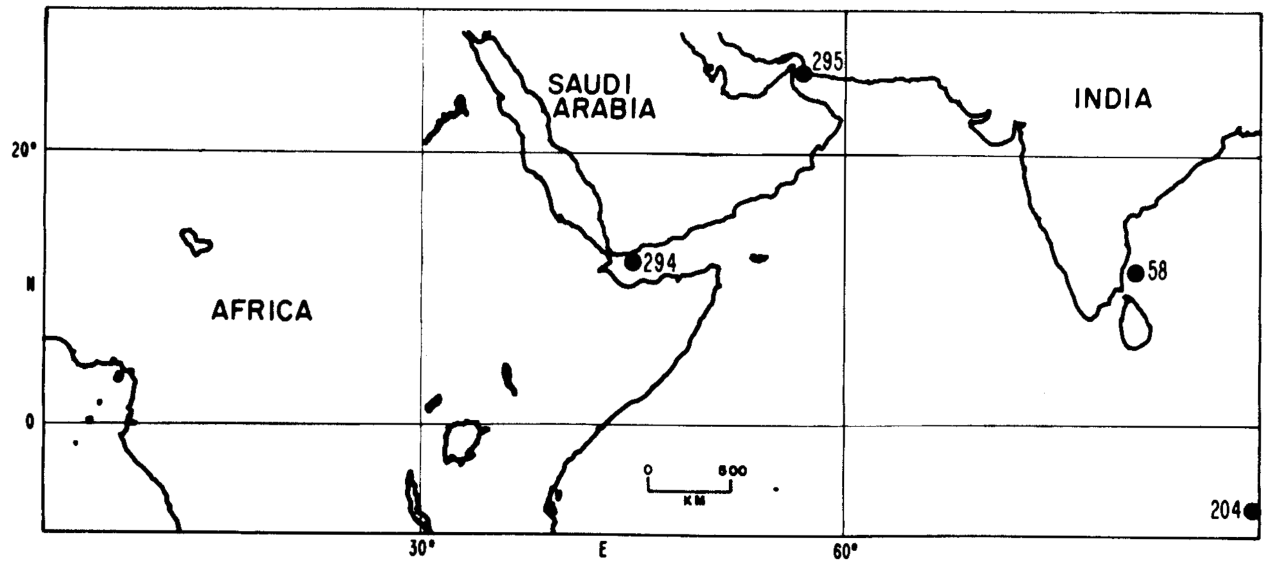
125°
E
130°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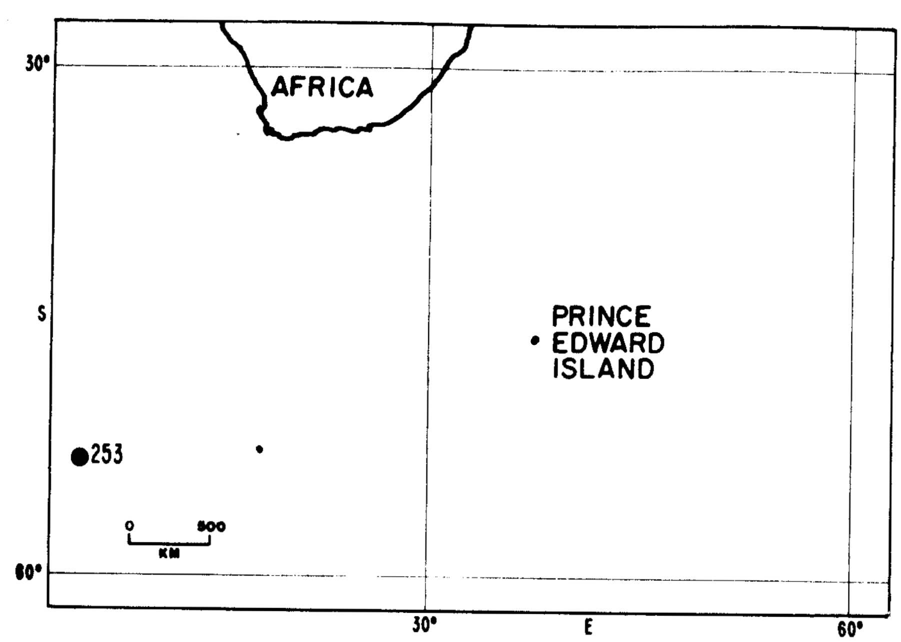
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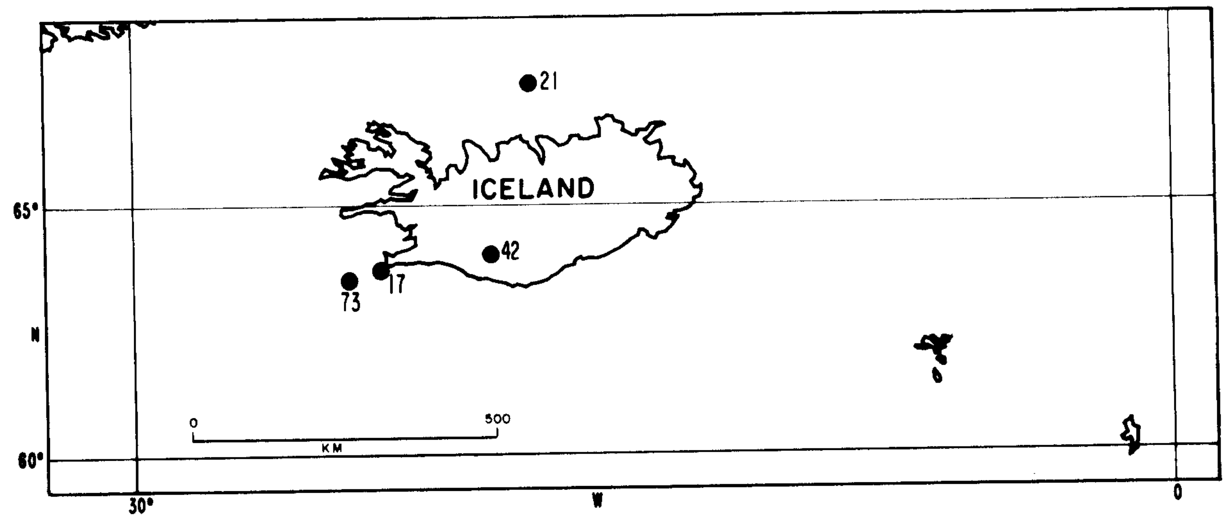
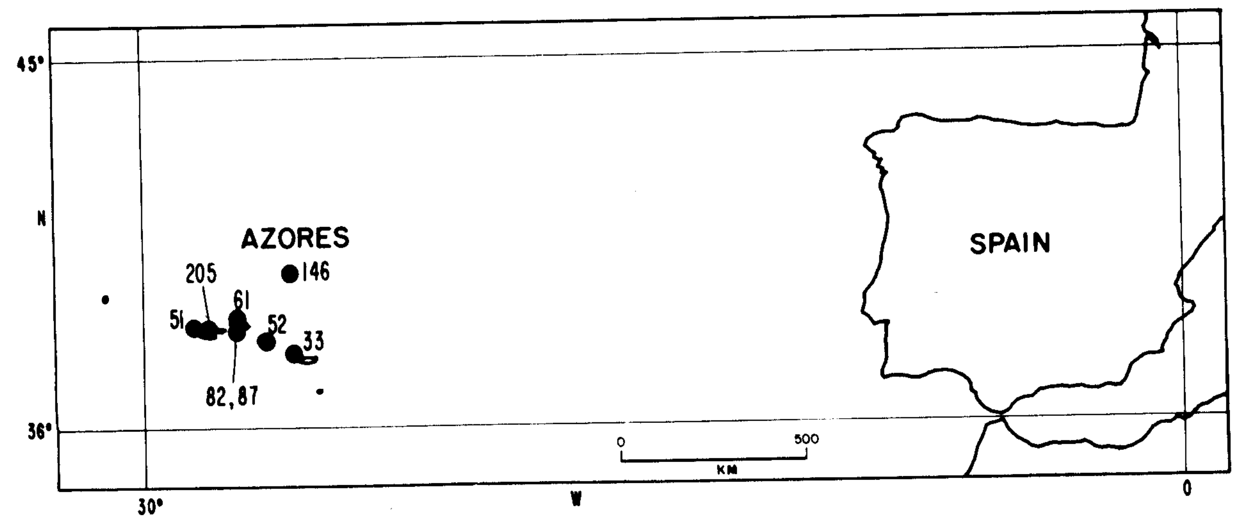
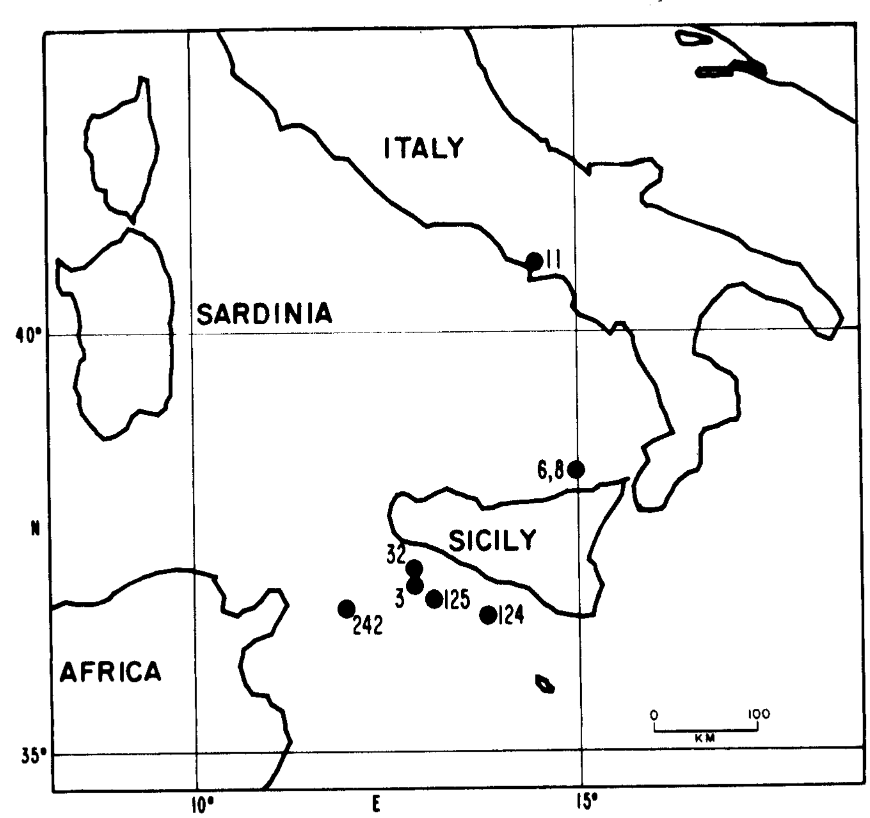
500
KM



ICELAND
21
42
17
73
65°
N
60°
0
500
KM
30°
W
0



45°
N
AZORES
SPAIN
205
146
61
51
52
33
82, 87
36°
0
500
KM
30°
W
0



ITALY
11
SARDINIA
40°
6,8
N
SICILY
32
3
125
124
242
AFRICA
0
100
KM
35°
10°
E
15°

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